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Optimization of United States Marine Corps Officer Career Path Selection

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THESIS

OPTIMIZATION OF UNITED STATES MARINE CORPS OFFICER CAREER PATH SELECTION

by

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September 2000

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The Marine Corps Manpower System is responsible for managing the Marine officer inventory. The system's primary objective is to maximize the Marine Corps' operational readiness through the assignment of officers to billets. While striving to fulfill billet requirements, the manpower system simultaneously develops the professional skills, or core competencies, that each officer must possess to be assigned to billets requiring more authority and responsibility. Therefore, officer careers (or career paths) must reflect a balance between fulfilling billet requirements and developing core competencies. Currently, Marine Corps manpower planners lack rigorous methods to assist them in understanding the effects of various personnel policy decisions on the average officer career path or the system's ability to meet future billet requirements.

To assist these planners, this thesis presents an integer program, the Officer Career Path Selection (OCPS) model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. This thesis uses data from the Infantry Marine Occupational Specialty (MOS) to illustrate that outputs from OCPS provide useful information regarding the number of annual Infantry officer accessions and the effects of potential manpower policy decisions.

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OPTIMIZATION OF UNITED STATES MARINE CORPS OFFICER CAREER PATH SELECTION

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

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DISCLAIMER

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The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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LIST OF ACRONYMS

BBILLET1	Aggregate billet name for B-Billet 1 billets
CLS	Aggregate billet name for Career Level School billets
COCDR	Aggregate billet name for Company Commander billets
CPG	Career Path Generator
CPLEX	Name of a software package for solving optimization problems
FIFO	First-In-First-Out
FINAL	Aggregate billet name for Final billets
GAMS	General Algebraic Modeling System
IANDI	Aggregate billet name for Inspector and Instructor billets
ILS	Aggregate billet name for Intermediate Level School billets
INSTR	Aggregate billet name for Instructor Duty billets
MOS	Marine Occupational Specialty
NFO	Naval Flight Officer
NONCDR	Aggregate billet name for Non-Commander billets
OCPS	Officer Career Path Selection Problem
OCPS-ECS	Officer Career Path Selection-Equal Cohort Size Problem
OPER1	Aggregate billet name for Operational 1 billets
OPER2	Aggregate billet name for Operational 2 billets
OTHERPC	Aggregate billet name for Other Post-Command billets
PLTCDR	Aggregate billet name for Platoon Commander billets
RECRUIT1	Aggregate billet name for Recruiting billets
SCHOOL	Aggregate billet name for Marine Officer Basic School – Infantry Officers Course
SEP	Aggregate billet name for Special Education Program billets
YCS	Year(s) of Commissioned Service

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EXECUTIVE SUMMARY

The Marine Corps Manpower System is responsible for managing the Marine officer inventory. The system's primary objective is to maximize the Marine Corps' operational readiness through the assignment of officers to billets. While striving to fulfill billet requirements, the manpower system simultaneously develops the professional skills, or core competencies, that each officer must possess to be assigned to billets requiring more authority and responsibility. Therefore, officer careers (or career paths) must reflect a balance between fulfilling billet requirements and developing core competencies. Currently, Marine Corps manpower planners lack rigorous methods to assist them in understanding the effects of various personnel policy decisions on the average officer career path or the system's ability to meet future billet requirements.

To assist these planners, this thesis presents an integer program, the Officer Career Path Selection (OCPS) model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. To make OCPS numerically tractable, this thesis assumes that billets with similar attributes are aggregated. In a smaller version of OCPS, i.e., OCPS with equal cohort size or OCPS-ECS, the number of officers assigned to the Marine Occupational Specialty (MOS) under consideration is the same every year.

To validate OCPS-ECS and illustrate its usefulness in decision-making, this thesis uses data from the 0302-Infantry MOS, hypothetical user parameter values, and a suppositional billet aggregation scheme. OCPS-ECS was implemented in an algebraic modeling system called GAMS. Using a Pentium III (500MHz) computer with 392

megabytes of random access memory, GAMS generates typical OCPS-ECS problems for the Infantry MOS in less than 20 minutes of CPU time and an optimization software package called CPLEX usually solves each generated problem in approximately five CPU minutes.

In addition to providing and describing useful information obtainable from OCPS-ECS, this thesis considered three applications. For the first application, OCPS-ECS helps to determine the number of officers to assign to the Infantry MOS each year. The second application uses OCPS-ECS to analyze the effects of decreasing the allowable shortfalls in a group of billets called the Post-Command billets. Based on the hypothetical user parameter values and the suppositional billet aggregation scheme, results from OCPS-ECS suggest that such a decrease can cause a dramatic increase in the number of officers assigned to another group of billets called the Supporting Establishment billets. This increase varies from approximately 48% to 105% over the total requirement for the Supporting Establishment billets. Finally, the last application examines the consequence of increasing the average core competency requirement for career paths in the solution to OCPS-ECS. In this case, results from OCPS-ECS indicate that more officers must be assigned to a critical (aggregate) billet, called the Platoon Commander billet, for longer periods of time in order to achieve higher core competency values. Unfortunately, accompanying this increase in assignments to the Platoon Commander billet is an undesirable decrease in the average tour length in another (aggregate) billet called the Company Commander billet.

In addition to the above applications, the following are also possible:

1. Determining the set of continuation rates that best meet the anticipated billet requirements for officers in a selected MOS.

2. Assessing the effect of new billet requirements on Marine Corps operational readiness as measured by, e.g., the manpower system's ability to simultaneously meet both existing and proposed billet requirements.

3. Quantifying the effects of new or, perhaps, non-traditional career paths on Marine Corps operational readiness.

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I. INTRODUCTION

The Marine Corps Manpower System is responsible for managing United States Marine Corps personnel. The system's four basic responsibilities are: the establishment of billet requirements, the determination of the extent to which these requirements can be fulfilled, the development of an inventory of qualified Marines, and, finally, the matching of Marines to billets designated for assignment. The goal of the manpower system is to place the right Marine in the right billet at the right time. Unfortunately, because total personnel requirements have always exceeded the inventory of available Marines, the manpower system operates in an environment in which this goal is unattainable. This over-constrained situation has become more challenging in recent years due to a congressionally-mandated force reduction which has resulted in a significant decrease in the inventory of Marines without an accompanying proportional decrease in corresponding personnel requirements. As a result, even the smallest changes in personnel requirements or the slightest modification in assignment policies can have a dramatic effect on the manpower system as a whole. The problem has become particularly acute in the management of the Marine Officer Corps.

In managing Marine officers, the manpower system balances two conflicting priorities: the desires of the Marine Corps and the personal preferences of individual officers. The objective of the Marine Corps in the assignment of officers to billets is twofold. The first is to maximize operational readiness, and the second is to professionally develop officers for future assignment to higher-ranking billets. Because of its effect on national security, the Marine Corps places more emphasis on the first

objective. Directed by personnel management policies, the manpower system seeks to meet this first objective by developing qualified officers and then matching them to a prioritized list of billets. Unfortunately, the manpower system's effort to fulfill billet requirements can also have a number of undesired effects, including a reduction in officer professional development or an increase in personnel attrition.

While trying to fulfill billet requirements, the manpower system simultaneously seeks to achieve the second Marine Corps objective which is to professionally develop officers for billets requiring more authority and responsibility. The Marine Corps expresses this professional development as a set of personal skills, termed *"core competencies"*, which define the qualifications required by an officer for continued service (i.e., promotion and assignment to more senior billets). Core competency development is a function of the sequence of billets held by a Marine officer over the course of his or her career, as well as the length of time spent in each billet. This billet sequence, or *career path*, evolves for each officer as the manpower system assigns the individual to new billets in an attempt to meet current Marine Corps personnel demands. Career paths reflect a balance between fulfilling billet requirements and developing core competencies. For instance, changes in the composition of the officer inventory or current billet requirements may shorten the average length of tours in certain billets considered essential to core competency development, such as unit command or resident professional military education.

The manpower system's effort to meet the desires of the Marine Corps often conflicts with officer preferences regarding personal career progression. Marine officers, regardless of their *Marine Occupational Specialty* or *MOS*, hold two general preferences

regarding their personal career progression. First, the majority of Marine officers seek to maintain a career path that develops their personal qualifications and makes them competitive for promotion and continued service. Second, many officers seek a measure of personal stability within their careers. Officers measure this stability in terms of a minimal number of reassignments during a career, consecutive assignments in a specific geographic region, or limited assignments to billets requiring family separation. The manpower system's failure to consider such individual preferences when seeking to fulfill billet requirements may lower morale and lead to higher officer attrition.

For officers in each MOS, there is a collection of acceptable career paths that support the manpower system's effort to fulfill billet requirements while providing for officer professional development and personal preferences. An understanding of MOS-specific career path characteristics allows the manpower system to set personnel assignment policies, such as specifying the average tour length for an officer in a unit command billet. Unfortunately, changes in billet requirements or personnel assignment policies can significantly alter the career path characteristics of an MOS.

In July 1999, the newly appointed Commandant of the Marine Corps, General James L. Jones, declared that the "...operating forces will not be the 'bill-payer' for other requirements." (Jones, 1999). He called for the manpower system to study alternative policies that would improve the fulfillment of personnel requirements within the Fleet Marine Force. With the size of the Marine Corps fixed by congressional mandate, any alternative policy would necessitate a shift of personnel from other billets, such as those in the supporting establishment or at joint-external commands. This shift in the assignment of personnel to different billets would necessarily result in changes to the

characteristics of acceptable career paths within a number of different MOS's. Recognition of such changes allows for better management of personnel in support of the primary manpower objectives of operational readiness and core competency development.

A. PROBLEM STATEMENT

Currently, manpower planners lack rigorous methods to provide them with a clear understanding of how personnel inventory or assignment decisions will affect the average officer's career path or the manpower system's ability to meet future billet requirements. Planners, who control the inventory, and *monitors*, who match officers to billets, require a tool that can assist them in understanding the best career path characteristics to meet the current or anticipated billet requirements for each officer's MOS. In addition, the tool should also provide planners and monitors with a means to evaluate the effect of proposed policy changes. For example, one approach to enhance the core competency of Infantry officers is to increase the tour length for their platoon commander billets. Doing so, however, may increase the number of officers eligible to fill the company commander billets during the latter part of their career. If manpower planners do not adjust the number of company commander billets to accommodate this increase, the opportunity for a company commander assignment will decrease. Consequently, this decrease in command opportunity may lower morale and lead to higher attrition among Infantry officers. Currently, the Marine Corps has no tool or rigorous methodology to estimate the additional number of Infantry officers eligible to fill the company commander billets that would result from an increase in the tour length of the platoon commander billets.

B. THESIS OUTLINE

Chapter II describes the various aspects of the Marine Corps Manpower System as they relate to officer billet requirements and career path development. Chapter III formulates the optimal career path selection (OCPS) problem as a mixed integer program. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. Chapter IV presents an algorithm for generating a key piece of input data to OCPS, i.e., a collection of acceptable career paths. In addition, Chapter IV also provides sample outputs from OCPS and illustrates their usefulness in several applications. Finally, Chapter V provides conclusions and recommendations.

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II. THE MARINE CORPS MANPOWER SYSTEM

This chapter describes the way in which the Marine Corps manages the careers of its officers. The first section describes the management of officer accessions, MOS assignment, and year-to-year retention. The second section discusses the development of officer billet requirements. The last two sections explain the interaction between the officer inventory and billet requirements in terms of career path and core competency development.

A. OFFICER INVENTORY

The Marine Corps currently maintains a personnel inventory of over 17,000 officers in 38 basic MOS's. For each fiscal year, Congress establishes the size, or *end-strength*, of the Marine Corps officer inventory. Constrained by the end-strength, the manpower system seeks to "shape" the Marine officer inventory to best meet prescribed billet requirements. The established officer end-strength drives many aspects of the manpower environment, including officer recruiting, promotion rates, and reassignment policies. For example, to maintain its prescribed end-strength, the Marine Corps commissions over 1000 new second lieutenants each year to replace officers who separate or retire.

During basic training, the Marine Corps assigns each newly commissioned officer a primary MOS which designates the field of expertise in which the individual will serve while on active duty. The MOS assignments for each year's set of newly commissioned officers, or *year group*, reflect the anticipated Marine Corps personnel requirements for each of the different MOS's. Because these personnel requirements vary greatly with

MOS, there is a wide range in the number of officers assigned to each of the MOS's. Figure 1 shows the current and projected officer MOS classification.

MOS	Description	Fraction of Officer Pop.	New Officer MOS Assignments FY00	FY01	2-year Average	Percent of Assignments
0180	Adjutant	2.42%	49	51	50	3.53%
02XX	Intelligence	4.65%	88	99	93.5	6.59%
0302	**Infantry**	14.86%	**190**	**206**	**198**	**13.96%**
0402	Logistics	8.59%	127	131	129	9.10%
0602	Communications	5.09%	97	109	103	7.26%
0802	Artillery	6.08%	87	97	92	6.49%
1302	Engineer	3.00%	44	43	43.5	3.07%
1802	Tank	1.39%	20	17	18.5	1.30%
1803	Assault Amphibious Vehicle	1.05%	12	12	12	0.85%
3002	Ground Supply	4.46%	82	82	82	5.78%
3404	Financial Management	2.06%	36	36	36	2.54%
4302	**Public Affairs**	0.83%	**12**	**10**	**11**	**0.78%**
4402	Judge Advocate	2.79%	43	45	44	3.10%
5803	Military Police	1.20%	21	21	21	1.48%
6002	Aircraft Maintenance	1.73%	30	29	29.5	2.08%
6602	Aviation Supply	1.23%	17	18	17.5	1.23%
7208	Air Support Control	1.74%	32	32	32	2.26%
7210	Air Defense Control	1.31%	15	14	14.5	1.02%
7220	Air Traffic Control	1.11%	12	10	11	0.78%
75XX	**Pilot or Naval Flight Officer**	34.40%	**369**	**391**	**380**	**26.80%**
		100.00%	1383	1453	1418	100.00%

Figure 1. Officer MOS assignments during basic training for fiscal years 2000 and 2001. Only twenty-three of the thirty-eight basic officer MOS's are assigned to newly commissioned officers. Twenty of these twenty-three MOS's are shown. The 02XX-Intelligence and 75XX-Pliot or Naval Flight Officer (NFO) entries are each an aggregation of two or more similar MOS's. Note that there is a wide range in the number of new officers assigned to each of the twenty MOS's. Five MOS's (0302-Infantry, 0402-Logistics, 0602-Communications, 0802-Artillery, and 3002-Ground Supply) comprise over 40% of the assigned officers. When these five fields are combined with 75XX-Pilot or NFO, only 30% of the officer year group remains to be assigned to the other fourteen MOS's. Changes in the manpower policies for these larger MOS's have a proportionately greater effect on the entire Marine Officer Corps. Finally, observe that the largest individual MOS, 0302-Infantry, also receives the highest proportion of new officer assignments.

Following basic training, the size of an officer year group decreases over time due to personnel attrition. Most types of officer attrition are under the limited control of the manpower system and include voluntary separation, involuntary separation (force reduction), retirement, and promotion failure. As a result, in any given year, only a

portion of the officers from the original year group is available for assignment to billets. By the time the year group reaches thirty *years of commissioned service* (YCS), only one or two very senior officers still remain on active duty. Traditionally, the officer population of any MOS suffers its highest attrition at two points: the termination of initial service contracts (YCS 4 to 7) and the qualification for retirement (approaching YCS 20). Figure 2 displays historical percentages (or *continuation fractions*) of Infantry officers who still serve in the Marine Corps after each year of commissioned service. The continuation fractions of other MOS's are similar.

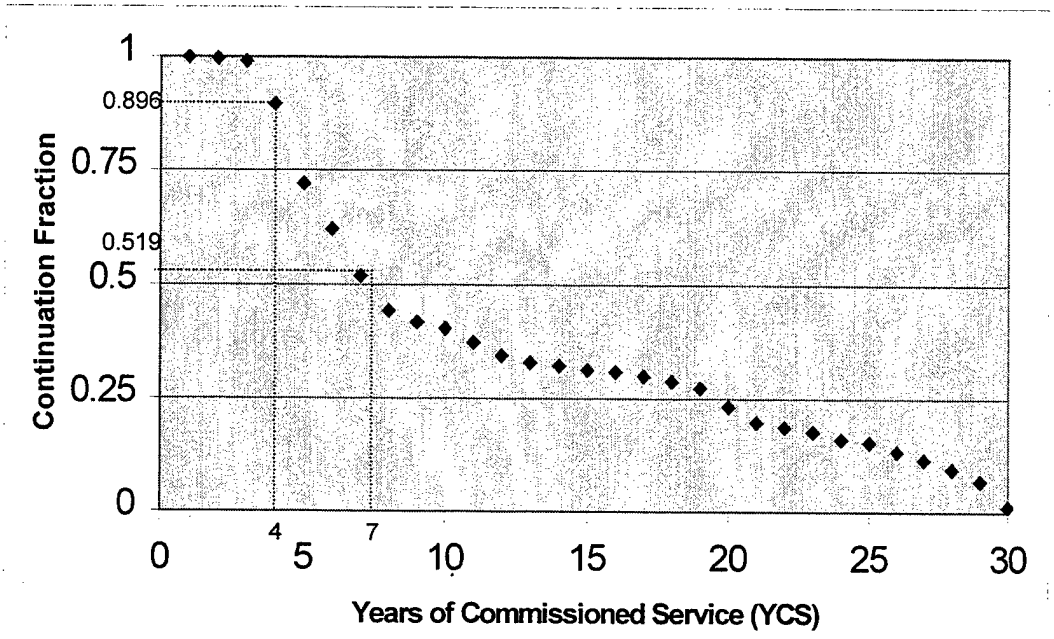

Figure 2. Historical continuation fractions for 0302-Infantry officers (based on the average infantry officer rates of continuation for fiscal years 1997, 1998, and 1999). Note the steep decline in retention from YCS 4 to YCS 7. This drop generally corresponds to the voluntary separation of junior officers following the expiration of their initial service contracts. Although less significant, the other notable decline occurs as YCS approaches twenty years. This drop corresponds to voluntary and involuntary officer retirement at twenty years of active service (which may be realized a few years prior to twenty years of *commissioned* service).

Because promotion and attrition rates vary across different MOS's and over time, continuation fractions can differ significantly between MOS's. With few means of

influencing continuation fractions for an MOS, manpower planners can do little but watch as fluctuations in retention wreak havoc on their ability to meet billet requirements. An "*under*" MOS has lower-than-desired continuation rates and therefore fewer Marine officers than required. As a result, the assignment policies for an "under" MOS are crafted to ensure that the most critical billets are filled, oftentimes to the detriment of the career paths of officers in that MOS. An "*over*" MOS has higher-than-necessary continuation rates and therefore more Marine officers than required. The excess personnel inventory in these fields reduces an officer's opportunity to hold billets considered essential to the development of his or her core competencies. For these out-of-balance MOS's in particular, manpower decision-makers must choose between two unappealing alternatives: fail to fill critical billets or fail to place officers in career paths that develop requisite skills for future service.

B. OFFICER BILLET REQUIREMENTS

The Marine Corps Manpower System uses three consecutive processes to determine officer billet requirements. Listed in sequence, these include *force structure*, *manning,* and *staffing*. The force structure process develops a set of billet requirements that would provide the Marine Corps with sufficient capabilities to successfully accomplish its current and future missions. However, in practice, some of these billet requirements cannot be filled because not all officers in the Marine Corps are available to fill billets. Officers who cannot fill billets are typically in training or in transit between duty stations. In fiscal year 1999, the force structure development process produced a requirement consisting of 16,037 billets. In the same year, the Marine Corps had 17,878 officers, but only 14,471 were available to fill billets. In other words, only 14,471

officers were part of the *operating force*. Thus, the next process in the sequence, the manning process, prioritizes the billets from the force structure development process and produces a smaller set of billet requirements that better suits the size of the current operating force. Finally, the staffing process reconciles the manning billet requirements with the size and composition (in terms of ranks and MOS's) of the operating force. Specifically, the staffing process prioritizes the billets that "survive" the manning process and determines which should be designated for the actual assignment of personnel. A billet may be left "unfilled" because it is not critical and/or there are not sufficient officers with suitable rank, training, and experience to fill it. One end product of the staffing process is a list of billets designated for officer assignment or, simply, *staffing goals*. Monitors complete the staffing process by using staffing goals as guidelines in assigning officers to billets.

Associated with each billet requirement are its description, rank (paygrade), Marine Occupational Specialty (MOS), specific unit, and the number of personnel required. The list below describes each of these elements.

1. The billet description defines the type of job that an assigned officer holds, such as rifle company commander or squadron operations officer.

2. Each officer billet also has an associated rank. Generally, the manpower system assigns officers to billets commensurate with their present rank; however, current manpower policy allows some deviation. Specifically, an officer can fill a requirement if the individual is within a single paygrade of the billet's designated rank. For instance, if necessary, either a captain (O-3) or lieutenant colonel (O-5) can fill a billet requiring an officer with the rank of major (O-4).

3. Each billet also specifies the MOS an assigned officer must hold. An officer's MOS determines the subset of all billets to which he or she may be assigned. Billets can require an officer to hold a certain primary MOS (e.g., 0302-Infantry, 0802-Artillery) or one of a group of MOS's (e.g., 9911-Unrestricted Ground officer which combines all primary ground combat arms MOS's).

4. For each billet there is an associated Marine unit at which the assigned officers must perform their duties. For instance, there is a rifle company commander billet at each of the Marine Corps' twenty-four infantry battalions, such as 3rd Battalion, 1st Marines.

5. Finally, each billet also specifies the required number of officers. For instance, the rifle company commander billet at 3rd Battalion, 1st Marines requires three officers, one for each of the unit's three rifle companies.

C. CAREER PATHS

The sequential reassignment of an officer in a given MOS to fill billets commensurate with his or her current rank leads to the development of a *career path.* Rather than being predetermined, an officer's career path evolves over the period of his or her active service in the Marine Corps. For certain officers, a career path can extend for thirty years and include more than a dozen billets as they progress from the rank of second lieutenant to general.

Regardless of MOS, a career path consists of rotating assignments to billets in one of four broad areas: Fleet Marine Force (warfighters), supporting establishment (recruiters, instructors, etc.), resident professional military education, and joint-external commands. As mentioned in Chapter I, it is the manpower system's effort to meet billet

requirements in each of these areas that largely determines the collection of acceptable career paths for a given MOS. Because acceptable career paths require a rotation in billet assignments, and certain billets require officers with a particular rank or level of experience, clearly not every possible combination of billet sequences constitutes a valid career path.

A career path is a function not only of the sequence of billets, but also the duration of time or *tour length* spent in each billet. It is not uncommon for two career paths to have exactly the same billet sequence, but distinctly different corresponding tour lengths for each assignment. Because it is possible to express tour length in units as small as days, it would be extremely unlikely for any two Marine Officers to have followed exactly the same career path.

D. CORE COMPETENCY DEVELOPMENT

With a primary focus on fulfilling billet requirements, the manpower system also must ensure that career paths in each MOS develop officers for assignment to more senior billets. Recently, the manpower system has focused on specifically identifying the core competencies required by officers in each MOS during each stage of their careers. These core competencies describe the skill set that an officer should gain from his or her billet assignments at each succeeding rank. The most critical aspects of core competency development occur at the junior ranks where there is a strong focus on reinforcing fundamental MOS skills. For the majority of MOS's, core competency development focuses most strongly on assignment to unit command billets in the Fleet Marine Force (e.g., rifle company commander, squadron commander). Figure 3 shows the core competencies required for combat arms officers (0302-Infantry, 0802-Artillery, and

18XX-Armor/Mechanized Vehicle) for the ranks of second lieutenant to lieutenant colonel.

Combat Arms Core Competencies

(Excerpted from 1999 Manpower Core Competency Working Group Report)

2nd / 1st Lieutenants

1) Proficient in company level tactics/weapons/weapons employment
2) Capable/comprehension of battalion staff procedures (S-1, S-3A, S-4A)
3) Capable of company executive officer tasks
4) Capable of supervising/sustaining maintenance
5) Experience in a variety of MOS specific billets
6) Capable of performing non-MOS specific duties (B-billet)

Captains

1) Capable of performing as a battalion S-3A/S-4
2) Understanding of combined arms tactics
3) Skill sets acquired from company command experience
   a) Balancing mission requirements and taking care of Marines
   b) Application of fairness and justice (non-judicial punishment)
   c) Moral and ethical leadership
4) B-Billet experience
   a) Experience with a variety of MOS's
   b) Greater exposure to staff non-commissioned officers
   c) Exposure to non-MOS specific tasks

Majors

1) Capable of serving as a battalion executive officer/S-3
2) Capable of serving as a regimental/division staff officer
3) Understanding of MEF-level tactics/weapons employment
4) Proficiency in planning and employment of combined arms

Lieutenant Colonel

1) Capable of performing as an MOS specific battalion commander
2) Capable of performing as a principal staff officer at division level or above
3) Skill sets acquired from battalion commander experience
   a) Understanding of how to fight a division
   b) Gains in operational experience
   c) Exercising the combined arms team (unit attachments)
   d) Ability to integrate battlefield functions

Figure 3. Core competency requirements for combat arms MOS's (0302-Infantry, 0802-Artillery, and 18XX-Armor/Mechanized Vehicle). The essence of core competency development occurs at the ranks of 2nd/1st lieutenant and captain where there is a strong focus on MOS-specific skills such as weapons employment, maintenance, and unit organization. Assignment to certain billets such as company command is deemed essential to core competency development. Core competency requirements for lieutenant colonels become extremely broad because billets at that rank and future assignments in more senior ranks vary widely.

Most importantly, core competency development seeks to advance the qualifications of an officer to allow for subsequent assignment to intermediate-level

command at the rank of lieutenant colonel (infantry battalion, aircraft squadron, etc.). As this command assignment normally occurs at sixteen or seventeen years of commissioned service, core competency development focuses mainly on the first fifteen years of an officer's career. Career paths that fail to assign officers to billets critical to core competency development may be necessary to fulfill certain requirements; however, they decrease the inventory of officers considered "qualified" for intermediate level command. As discussed in Chapter I, the manpower system must balance meeting billet requirements against satisfying the core competency development for officers in each MOS. To aid in this effort, the next chapter proposes an optimization model for identifying a set of career paths that best balances these two manpower priorities.

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III. OFFICER CAREER PATH SELECTION MODEL

This chapter presents an optimization model for determining a mix of career path "assignments" for each new cohort of officers that best meets specified billet requirements. The model addresses one MOS at a time and, therefore, considers only the set of officers, billets, and career paths within the designated MOS.

The first section discusses the assumptions necessary for formulating such a model as a mixed integer linear program. The second section describes a mathematical representation of officer career paths. The next two sections present two versions of the model formulation, the second of which makes a simplifying assumption. Finally, the last section reviews related work in the literature.

A. MODEL ASSUMPTIONS

Because of the complexity and diversity of the Marine Corps' personnel policy and structure, the modeling of officer career paths and billet assignments can quickly become overwhelming. To make such a problem numerically tractable and solvable on a reasonably capable personal computer, the following assumptions are necessary:

1. Although it may be more realistic to use time units of days, for example, to express billet tour lengths, the number of potential career paths for any MOS would be nearly infinite. To reduce the resulting size of the model, this thesis assumes that all temporal data are in units of years.

2. Because an officer's career can be less than a year (due to legal separation, medical discharge, etc.) or as long as thirty years, the length of officer career paths is stochastic. However, allowing officer career path lengths to vary probabilistically would result in a stochastic programming problem that is beyond the scope of this thesis. This

thesis assumes that the length of every career path is constant. Specifically, the implementation in Chapter IV assumes that the length of every career path is thirty years, i.e., the length of the longest possible officer career.

3. Instead of addressing individual billets, the model aggregates billets with similar characteristics into groups. Billets that have comparable officer rank requirements, tour lengths, and career path position in terms of YCS are candidates for aggregation. Thus, the term "billet" henceforth refers to an aggregation of similar billets. Likewise, the term "billet requirement" refers to the number of officers required to fill the individual billets in a particular aggregated group. For instance, the term "Instructor Billet" can collectively refer to instructional billets for Infantry captains at the United States Naval Academy, Officer Candidate School, The Basic School, and the Army School of Infantry. If each of these four schools has two instructional positions for Infantry officers, the numerical requirement for the aggregated "Instructor Billet" is eight.

B. CAREER PATH REPRESENTATION

In practice, the Marine Corps Manpower System does not assign a newly commissioned officer to a specific career path for his or her respective MOS. Instead, an officer's career path evolves through billet reassignment over a period of many years. The monitors in the manpower system designate an officer for reassignment only when the individual is due for rotation. Because reassignment is dependent on the nature of an officer's current billet, it generally occurs at intervals of between one and four years.

The model presented in this chapter takes a different, but equivalent, view of officer career paths. For planning purposes, the model assumes that there is a collection

of "valid" career paths for each MOS, and that upon MOS designation during basic training, the Marine Corps assigns each newly commissioned officer to one path in this collection. This thesis assumes that a path is "valid" if it consists of a sequence of billets with appropriate duration that is meaningful to officers and personnel managers. Mathematically, it is possible to represent each career path as a vector of zeros and ones. To illustrate, consider the fictitious 0X02-Warrior MOS (or simply Warrior MOS) with the following aggregated billet requirements:

Billet	Requirement
A	10
B	20
C	5
D	5

In this scenario, officers in the Warrior MOS have a maximum possible career length of ten years. Thus, every officer must leave active duty by the completion of his or her tenth year of commissioned service. Figure 4 depicts several possible career paths derived from the four Warrior MOS billets. Each career path is ten years long and consists of a valid sequence of billets with appropriate duration. Recall that two or more career paths can have the same billet sequence, but not all billets have the same tour lengths. For example, in Figure 4, career paths 1 and 2 have billets A, B, C, and D in the same sequence but with different tour lengths.

YCS	Career Paths			
	Path 1	Path 2	Path 3	Path 4
Year 1	Billet A	Billet A	Billet B	Billet B
Year 2	Billet A	Billet A	Billet B	Billet B
Year 3	Billet B	Billet A	Billet A	Billet B
Year 4	Billet B	Billet B	Billet A	Billet A
Year 5	Billet B	Billet B	Billet A	Billet A
Year 6	Billet C	Billet B	Billet C	Billet A
Year 7	Billet C	Billet B	Billet C	Billet A
Year 8	Billet C	Billet C	Billet D	Billet D
Year 9	Billet D	Billet C	Billet D	Billet D
Year 10	Billet D	Billet D	Billet D	Billet D

Figure 4. Sample officer career paths for the Warrior MOS. Paths 1 and 2 have the same billet sequence, but the tour lengths are different.

Although easily understood, the career path representation in Figure 4 is not convenient for mathematical modeling. Observe that path 1 in Figure 4 contributes to billet A's annual requirement in years 1 and 2. The following binary vector in $\Re^{10}$ represents path 1's contribution to billet A's annual requirement in a more convenient form.

$$\text{Path 1's contribution to billet A's requirements in a 10 year period} = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

The "one" in the i^{th} position indicates that the career path contributes to billet A's requirement in year i. Similarly, path 1's contributions to the other three billet requirements can be represented as follows:

Path 1's contribution to billets B, C, and D in a 10 year period

$$\text{billet B} = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \text{billet C} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}, \text{and billet D} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 1 \end{bmatrix}$$

Finally, concatenating the four binary vectors provides an alternate representation for career path 1 as displayed in Figure 5, along with those of paths 2, 3, and 4.

		Career Paths			
	YCS	Path 1	Path 2	Path 3	Path 4
Billet A	Yr 1	1	1		
	Yr 2	1	1		
	Yr 3		1	1	
	Yr 4			1	1
	Yr 5			1	1
	Yr 6				1
	Yr 7				1
	Yr 8				
	Yr 9				
	Yr 10				
Billet B	Yr 1			1	1
	Yr 2			1	1
	Yr 3	1			1
	Yr 4	1	1		
	Yr 5	1	1		
	Yr 6		1		
	Yr 7		1		
	Yr 8				
	Yr 9				
	Yr 10				
Billet C	Yr 1				
	Yr 2				
	Yr 3				
	Yr 4				
	Yr 5				
	Yr 6	1		1	
	Yr 7	1		1	
	Yr 8	1	1		
	Yr 9		1		
	Yr 10				
Billet D	Yr 1				
	Yr 2				
	Yr 3				
	Yr 4				
	Yr 5				
	Yr 6				
	Yr 7				
	Yr 8			1	1
	Yr 9	1		1	1
	Yr 10	1	1	1	1

Figure 5. Warrior MOS career paths expressed in binary notation (zeros omitted).

The career paths depicted in Figures 4 and 5 reflect the contribution to the four billet requirements of only a single year group (cohort) of officers in the Warrior MOS. Because the Marine Corps commissions new officers each year, there are ten cohorts of newly commissioned officers over the ten-year planning horizon, where officers in cohort *t* would be commissioned and assigned the Warrior MOS in year *t*. When assigned to the same career path, officers in different cohorts contribute to the same sequence of billet requirements in different years. Consider the ten cohorts for path 1 in Figure 6.

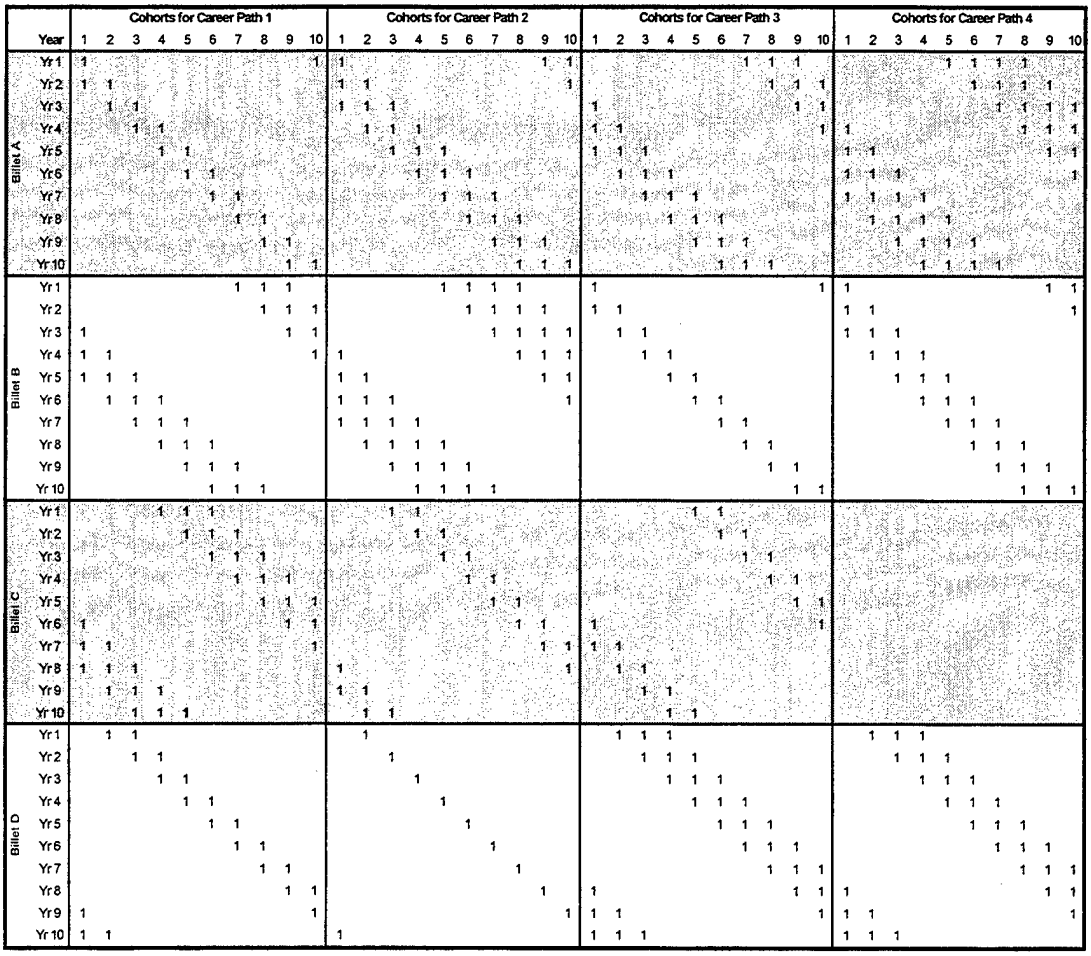

Figure 6. Cohort representation for the Warrior MOS career paths of Figure 5 (zeros omitted). There are ten officer cohorts for each career path. Each cohort represents a group of officers commissioned during each year in a ten-year period. The representation for cohort *t+1* is the same as cohort *t*, but shifted downward by one year. When the billet contributions cross over to the next ten-year period, they are "looped" back to the beginning of the first ten-year period. For example, cohort 5 of career path 1 contributes to billet C's requirements in years 10, 11, and 12. However, the table lists the contributions in years 11 and 12 as years 1 and 2 instead. Therefore, the ten-year period in this table represents a recurring ten-year period.

Officers in cohort 1 fill billet A's requirement in years 1 and 2. Because officers in cohort 2 are commissioned in year 2, they fill billet A's requirement in years 2 and 3, instead. This one-year shift between cohorts 1 and 2 is the same for the succeeding billets. In this manner, the career path representation for cohort 2 is the same as cohort 1, but shifted downward by one year.

To avoid representing the subsequent ten-year period as another binary vector in $\Re^{10}$, year 11, or the first year in the subsequent ten-year period, is considered as year 1. Thus, officers in cohort 10 of career path 1 fill billet A's requirement in year 10 and year 1, i.e., year 11. As another example, consider officers in cohort 5 of career path 1. These officers fill billet C's requirement in year 10, 1, and 2, where years 1 and 2 are equivalent to years 11 and 12. In this sense, the zeros and ones in Figure 6 are a matrix of cohort-career path contributions to billet requirements over a recurring ten-year period.

To this point, the career path representation reflects the assumption that each fictitious Warrior officer serves on active duty for exactly ten years. The career path cohorts in binary notation must additionally account for officer attrition due to voluntary separation, failed promotion, MOS reassignment, etc. Only a portion of the officers in each cohort who fill billets in year t will be available to fill billets in year $t + 1$. To reflect this, Figure 7 shows the career path cohorts of Figure 6 with fictitious continuation fractions applied. Observe that the fictitious fraction of the cohort remaining at each year t decreases monotonically from 1.000 during the commissioning year ($t = 1$) to 0.10 during the last year ($t = 10$) of an officer's career in the Warrior MOS.

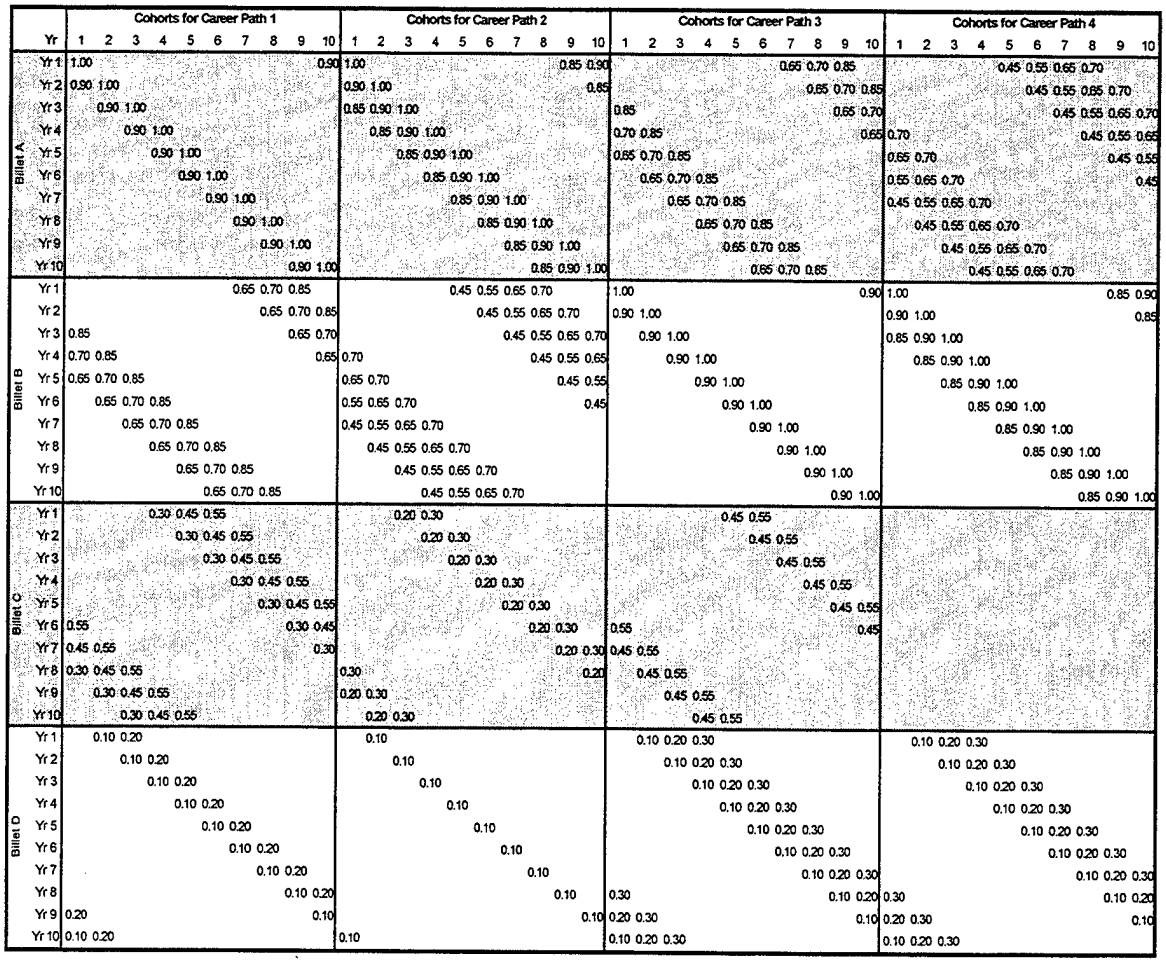

Figure 7. 0X02-Warrior career path cohorts with continuation fractions applied (zeros omitted in blank cells). For each billet, the representation depicts the fraction of the original officers remaining in each career path cohort during each of the ten years of the planning horizon. As can be seen in the first cohort of each career path, the fictitious continuation fraction decreases monotonically from 1.00 during year 1 to 0.10 in year 10, the final year of service for a fictitious Warrior officer.

C. PROBLEM FORMULATION

Given the representation of career paths described in the preceding section, the career path selection problem reduces to one of determining the number of officers from each cohort to assign to each career path in order to best meet billet requirements for a given MOS.

		Path 1 Cohort 2	Path 2 Cohort 5	Path 3 Cohort 9	Path 4 Cohort 3			
Officers Assigned		10	5	5	20	Officers to Billets	Billet Requirement	Difference
Billet A	Yr 1			0.85		4.25	10	-5.75
	Yr 2	1.00		0.70		13.50	10	3.50
	Yr 3	0.90		0.65		12.25	10	2.25
	Yr 4					0.00	10	-10.00
	Yr 5		1.00			5.00	10	-5.00
	Yr 6		0.90		0.70	18.50	10	8.50
	Yr 7		0.85		0.65	17.25	10	7.25
	Yr 8				0.55	11.00	10	1.00
	Yr 9				0.45	9.00	10	-1.00
	Yr 10					0.00	10	-10.00
Billet B	Yr 1		0.45			2.25	20	-17.75
	Yr 2					0.00	20	-20.00
	Yr 3				1.00	20.00	20	0.00
	Yr 4	0.85			0.90	26.50	20	6.50
	Yr 5	0.70			0.85	24.00	20	4.00
	Yr 6	0.65				6.50	20	-13.50
	Yr 7					0.00	20	-20.00
	Yr 8		0.70			3.50	20	-16.50
	Yr 9		0.65	1.00		8.25	20	-11.75
	Yr 10		0.55	0.90		7.25	20	-12.75
Billet C	Yr 1					0.00	5	-5.00
	Yr 2		0.30			1.50	5	-3.50
	Yr 3		0.20			1.00	5	-4.00
	Yr 4			0.55		2.75	5	-2.25
	Yr 5			0.45		2.25	5	-2.75
	Yr 6					0.00	5	-5.00
	Yr 7	0.55				5.50	5	0.50
	Yr 8	0.45				4.50	5	-0.50
	Yr 9	0.30				3.00	5	-2.00
	Yr 10					0.00	5	-5.00
Billet D	Yr 1	0.10			0.20	5.00	5	0.00
	Yr 2				0.10	2.00	5	-3.00
	Yr 3					0.00	5	-5.00
	Yr 4		0.10			0.50	5	-4.50
	Yr 5					0.00	5	-5.00
	Yr 6			0.30		1.50	5	-3.50
	Yr 7			0.20		1.00	5	-4.00
	Yr 8			0.10		0.50	5	-4.50
	Yr 9					0.00	5	-5.00
	Yr 10	0.20			0.30	8.00	5	3.00

Figure 8. Selected cohorts from the four career paths depicted in Figure 7. The number of officers assigned to each of the four cohort-career path combinations determines the number of officers who actually fill a specific billet in year *t*. For instance, the number of officers filling billet B in year 5 is equal to 10*0.70 + 5*0.0 + 5*0.0 +20*0.85 = 24.

Using the cohort-career path combinations in Figure 7, Figure 8 depicts the results of assigning ten officers from cohort 2 to career path 1, five from cohort 5 to career path 2, five from cohort 9 to career path 3, and twenty from cohort 3 to career path 4. In year 5 (see the shaded row of Figure 8), there are 24 (or 10*0.70 + 5*0.0 + 5*0.0 +20*0.85) officers assigned to billet B. Because the requirement for billet B is only 20, there are four officers too many.

The goal is to assign officers to cohort-career path combinations so that the total number of officers over and under the billet requirements is minimized. However, the assignments cannot be made arbitrarily because they must satisfy constraints concerning the average tour length in certain billets, the fraction of officers who hold a specific billet during their career, and the development of core competencies. Below is a mathematical formulation for the career path selection problem for a given MOS.

Indices:

b	Billet-type (platoon commander, recruiting duty, etc.)
p	Career path (sequence of billets and tour lengths)
c, c'	Cohort group (group of officers commissioned in a given year)
t	Year of planning horizon (career length)

Sets:

B	All billets
C	All cohort groups (years in planning horizon)
CP	Acceptable career paths

Problem Data:

$OverPen_b$	Penalty for each officer over the requirement for billet b
$UnderPen_b$	Penalty for each officer under the requirement for billet b
$Rqmt_{b,t}$	Number of officers required to fill billet b, in year t
$UnderDev_{b,t}$	Allowed shortfall in the number of officers required to fill billet b, in year t
$OverDev_{b,t}$	Allowed surplus in the number of officers required to fill billet b, in year t
$InPathYear_{c,p,b,t}$	Value 1 if cohort group c, of career path p, contains billet b, in year t; 0 otherwise
$InPath_{c,p,b}$	Value 1 if cohort group c, of career path p, contains billet b; 0 otherwise
$ContFrac_{c,t}$	Fraction of officers in cohort c who remain in service in year t
$MinOff_c$	Minimum number of newly commissioned officers in cohort c to be assigned the designated MOS

$MaxOff_c$	Maximum number of newly commissioned officers in cohort c to be assigned the designated MOS
$MinAvgTour_b$	Minimum average tour length in years required for billet b
$MaxAvgTour_b$	Maximum average tour length in years allowed for billet b
$MinFillFrac_b$	Minimum fraction of the officer population that must serve in billet b during career
$MaxFillFrac_b$	Maximum fraction of the officer population that can serve in billet b during career
$PlanHor$	Length of planning horizon in years
$UpShift$	Allowed fractional difference (excess) between number of officers assigned to cohort c in career path p and the average cohort size for career path p ($UpShift >= 1.0$)
$DnShift$	Allowed fractional difference (shortage) between number of officers assigned to cohort c in career path p and the average cohort size for career path p ($0 <= DnShift <= 1.0$)
$CoreCompPt_b$	Scalar value between 0 and 1 reflecting the contribution toward "core competency" of spending one year in billet b
$MinAvgCCPt$	Minimum "core competency" points required for the average officer career

Decision Variables:

$ASSIGN_{c,p}$	Number of officers from cohort c assigned to career path p
$OVER_{b,t}$	Number of officers over the requirement for billet b, during year t
$UNDER_{b,t}$	Number of officers under the requirement for billet b, during year t

Formulation:

The Optimal Career Path Selection (OCPS) Problem

$$Minimize \quad \sum_{b \in B} \sum_{t} \left\{ UnderPen_b * UNDER_{b,t} + OverPen_b * OVER_{b,t} \right\}$$

subject to

$$\sum_{p \in CP} \sum_{c \in C} \left\{ ContFrac_{c,t} * InPathYear_{c,p,b,t} * ASSIGN_{c,p} \right\} + UNDER_{b,t} - OVER_{b,t} = Rqmt_{b,t} \qquad \forall\, b, t \qquad (1)$$

$$UNDER_{b,t} \le UnderDev_{b,t} \qquad \forall\, b,\ t \qquad (2)$$

$$OVER_{b,t} \le OverDev_{b,t} \qquad \forall\, b,\ t \qquad (3)$$

$$MinOff_c \le \sum_{p \in CP} ASSIGN_{c,p} \le MaxOff_c \qquad \forall\, c \qquad (4)$$

$$MinAvgTour_b * \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} * InPath_{c,p,b} \le \sum_{p \in CP} \sum_{c \in C} \left\{ ASSIGN_{c,p} * \sum_{t} InPathYear_{c,p,b,t} \right\} \le MaxAvgTour_b * \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} * InPath_{c,p,b} \qquad \forall\, b \qquad (5)$$

$$MinFillFrac_b * \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} \le \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} * InPath_{c,p,b} \le MaxFillFrac_b * \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} \qquad \forall\, b \qquad (6)$$

$$DnShift * \left(\frac{\sum_{c' \in C} ASSIGN_{c',p}}{PlanHor} \right) \le ASSIGN_{c,p} \le UpShift * \left(\frac{\sum_{c' \in C} ASSIGN_{c',p}}{PlanHor} \right) \qquad \forall\, c,\ p \qquad (7)$$

$$\sum_{p \in CP} \sum_{c \in C} \left\{ ASSIGN_{c,p} * \sum_{b \in B} \left(CoreCompPt_b * \sum_{t} InPathYr_{c,p,b,t} \right) \right\} \ge MinAvgCCPt * \sum_{p \in CP} \sum_{c \in C} ASSIGN_{c,p} \qquad (8)$$

$$ASSIGN_{c,p} \ge 0 \quad \text{and integer} \quad \forall\, c,\ p \qquad (9)$$

$$UNDER_{b,t} \ge 0 \qquad \forall\, b,\ t \qquad (10)$$

$$OVER_{b,t} \ge 0 \qquad \forall\, b,\ t \qquad (11)$$

The objective function is the weighted difference between officer assignments and billet requirements. Penalty coefficients, $OverPen_b$ and $UnderPen_b$, allow the user to

place relative emphasis on minimizing the number of officers over or under each billet requirement. The "covering" constraint (1) calculates the number of officers over or under each billet requirement. The first term computes the number of officers assigned to billet b in year t. Slack and surplus variables, $OVER_{b,t}$ and $UNDER_{b,t}$, respectively, for each billet allow for deviation from the specified requirements. Constraints (2) and (3) ensure that the deviation from the specified requirement for each billet remains within acceptable limits. Constraint (4) restricts the number of officer accessions in each cohort to a specified range. Constraint (5) guarantees that the average tour length in a billet is within the specified range. Constraint (6) defines the minimum and maximum fraction of all officers who can serve in a specific billet. This constraint is relevant for "core competency" billets considered essential for the proper development of requisite skills in that MOS. Constraint (7) controls the variability in career path assignments from cohort to cohort. This constraint seeks to provide a measure of stability in the optimal career path mix from year to year. Constraint (8) ensures that the career path mix recommended by the model meets the minimum "core competency" requirement for the average officer in that MOS. Finally, constraint (9) restricts the number of officers assigned to a career path cohort to nonnegative integer values, while constraints (10), and (11) ensure that the slack and surplus variables are nonnegative.

D. SPECIAL CASE

In practice, it is undesirable for the variable $ASSIGN_{c,p}$ to fluctuate wildly between the different cohorts of a career path. Although it is possible to include constraints to limit this fluctuation, doing so dramatically increases the required solution time. Another alternative is to assume that $ASSIGN_{c,p}$ remains constant across the cohorts of a career

path, i.e., $ASSIGN_{c,p} = ASSIGN_p$ for all c. As a result of this restriction, it is also reasonable to ensure that the requirement for billet b is the same for all year t, i.e., $Rqmt_{b,t} = Rqmt_b$ for all t. Recall the covering constraint (1) from OCPS:

$$\sum_{p \in CP} \sum_{c \in C} \left\{ ContFrac_{c,t} * InPathYear_{c,p,b,t} * ASSIGN_{c,p} \right\} + UNDER_{b,t} - OVER_{b,t} = Rqmt_{b,t} \quad \forall\, b,\, t$$

Under the above assumptions, this constraint reduces to

$$\sum_{p \in CP} \left[ASSIGN_p * \sum_{c \in C} \left\{ ContFrac_{c,t} * InPathYear_{c,p,b,t} \right\} \right] + UNDER_{b,t} - OVER_{b,t} = Rqmt_b \quad \forall\, b,\, t \qquad (12)$$

Now, consider the application of this constraint to a specific billet. Recall the Warrior MOS scenario depicted in Figure 7. Figure 9 displays the contribution of ten officer cohorts using career path 1. If every cohort consists of five officers, then the number of officers assigned to billet B in a given year, i.e., year 3, is five times the sum of the continuation fractions for that row or $5*(0.85 + 0.0 + \ldots + 0.0 + 0.65 + 0.70) = 11$. Observe that each row in Figure 9 consists of exactly the same set of continuation fractions. Thus, the number of officers assigned to each year is equal to the number of officers annually assigned to the career path times the sum of the continuation fractions in each row, and these totals must be the same. Observe also that the sum of the continuation fractions is the same for each column.

		Cohorts for Career Path 1										
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	
$ASSIGN_{c,p}$		5	5	5	5	5	5	5	5	5	5	Officers to Billets
Billet B	Yr 1							0.65	0.70	0.85		11
	Yr 2								0.65	0.70	0.85	11
	Yr 3	0.85								0.65	0.70	11
	Yr 4	0.70	0.85								0.65	11
	Yr 5	0.65	0.70	0.85								11
	Yr 6		0.65	0.70	0.85							11
	Yr 7			0.65	0.70	0.85						11
	Yr 8				0.65	0.70	0.85					11
	Yr 9					0.65	0.70	0.85				11
	Yr 10						0.65	0.70	0.85			11

Figure 9. The effect on billet B of equal career path 1 cohort assignments. Each column and row consists of exactly the same set of continuation fractions. If five officers are assigned to each of the ten cohorts ($ASSIGN_{c,p} = ASSIGN_p = 5$), the first career path will contribute eleven officers to billet B during each year of the planning horizon. For instance in year 3, the number of officers filling billet B is 5*(0.85 + 0.0 + ... + 0.0 + 0.65 + 0.70) = 11.

Below is an expression for the column sum of the continuation fractions:

$$\sum_t \{ContFrac_{c,t} * InPathYear_{c,p,b,t}\}$$

As shown in Figure 9, this sum is the same for each cohort c. To simplify the notation, it is logical to drop the cohort index and rewrite the above expression as

$$\sum_t \{ContFrac_t * InPathYear_{p,b,t}\}$$

where $ContFrac_t$ is the fraction of officers in a cohort who remain in service in year t and $InPathYear_{p,b,t}$ equals 1 if career path p contains billet b in year t.

Based on the above observation, equation (12) is the same for all t. Thus, it can be written more compactly and without the index t as

$$\sum_{p \in CP} \left[ASSIGN_p * \sum_t \{ContFrac_t * InPathYear_{p,b,t}\} \right] + UNDER_b - OVER_b = Rqmt_b \qquad \forall b$$

where $OVER_b$ and $UNDER_b$ represent the number of officers over and under the number required for billet b, respectively.

In fact, the OCPS with equal cohort size assumption reduces to the following problem. (It should be noted that in keeping with the discussion above, several parameters and variables have been re-indexed; however, their names remain unchanged in order to preserve the relationship between the two models.)

Indices:

b	Billet-type (platoon commander, recruiting duty, etc.)
p	Career path (sequence of billets and tour lengths)
t	Year in planning horizon (career length)

Sets:

B	All billets
CP	Acceptable career paths

Data:

$OverPen_b$	Penalty for each officer over the requirement for billet b
$UnderPen_b$	Penalty for each officer under the requirement for billet b
$Rqmt_b$	Constant number of officers required to fill billet b
$UnderDev_b$	Allowed shortfall in the number of officers required to fill billet b
$OverDev_b$	Allowed surplus in the number of officers required to fill billet b
$InPathYear_{p,b,t}$	Value 1 if career path p contains billet b in year t; 0 otherwise
$InPath_{p,b}$	Value 1 if career path p, contains billet b; 0 otherwise
$ContFrac_t$	Fraction of officers who remain in service in year t
$MinOff$	Minimum number of newly commissioned officers to be assigned the designated MOS
$MaxOff$	Maximum number of newly commissioned officers to be assigned the designated MOS
$MinAvgTour_b$	Minimum average tour length in years required for billet b
$MaxAvgTour_b$	Maximum average tour length in years allowed for billet b
$MinFillFrac_b$	Minimum fraction of the officer population that must serve in billet b during career

$MaxFillFrac_b$	Maximum fraction of the officer population that can serve in billet b during career
$CoreCompPt_b$	Scalar value between 0 and 1 reflecting the contribution toward "core competency" of spending one year in billet b
$MinAvgCCPt$	Minimum "core competency" points required for the average officer career

Decision Variables:

$ASSIGN_p$	Number of officers per year group assigned to career path p
$OVER_b$	Number of officers over the requirement for billet b
$UNDER_b$	Number of officers under the requirement for billet b

Formulation:

Optimal Career Path Selection Problem with Equal Cohort Size (OCPS-ECS)

$$Minimize \quad \sum_{b \in B} \{UnderPen_b * UNDER_b + OverPen_b * OVER_b\}$$

subject to

$$\sum_{p \in CP} \sum_{t} \{ContFrac_t * InPathYear_{p,b,t} * ASSIGN_p\} + UNDER_b - OVER_b = Rqmt_b \quad \forall b \quad (13)$$

$$UNDER_b \leq UnderDev_b \quad \forall b \quad (14)$$

$$OVER_b \leq OverDev_b \quad \forall b \quad (15)$$

$$MinOff \leq \sum_{p \in CP} ASSIGN_p \leq MaxOff \quad (16)$$

$$MinAvgTour_b * \sum_{p \in CP} \{ASSIGN_p * InPath_{p,b}\} \leq \sum_{p \in CP} \left\{ASSIGN_p * \sum_{t} InPathYear_{p,b,t}\right\} \leq MaxAvgTour_b * \sum_{p \in CP} \{ASSIGN_p * InPath_{p,b}\} \quad \forall b \quad (17)$$

$$MinFillFrac_b * \sum_{p \in CP} ASSIGN_p \leq \sum_{p \in CP} \{ASSIGN_p * InPath_{p,b}\} \leq MaxFillFrac_b * \sum_{p \in CP} ASSIGN_p \quad \forall b \quad (18)$$

$$\sum_{p \in CP} \left\{ ASSIGN_p * \sum_{b \in B} \left(CoreCompPt_b * \sum_t InPathYear_{p,b,t} \right) \right\} \geq MinAvgCCPt * \sum_{p \in CP} ASSIGN_p \quad (19)$$

$$ASSIGN_p \geq 0 \quad \text{and integer} \; \forall p \quad (20)$$

$$UNDER_b \geq 0 \quad \forall b \quad (21)$$

$$OVER_b \geq 0 \quad \forall b \quad (22)$$

The above formulation does not include an analogous version of the stability constraint, i.e., constraint (7), because the assumption that $ASSIGN_{c,p} = ASSIGN_p$ for all c renders it superfluous. With the exception of the cohort and time indices, the objective function and the remainder of the constraints are analogous to those in OCPS.

E. RELATED WORK

Constraints (1) and (13) of the OCPS and OCPS-ECS problems, respectively, are related to the set-covering constraints in the literature. Schrage (1991) [see also Bausch, 1982] provides an overview of applications of set-covering or partitioning constraints that include the classic cutting stock and aircrew scheduling problems. In many respects, the aircrew scheduling problem (see Hoffman and Padberg, 1993) parallels the basic set-covering aspects of the officer career path selection problem. Without the consideration of cohorts or personnel attrition, the aircrew scheduling problem seeks to match an

aircrew inventory (Marine officers) to work schedules (career paths) to meet prescribed flight requirements (billets).

The current literature does not include the application of set-covering or partitioning constraints to military manpower problems. Most military applications of set-covering or partitioning problems relate to the operational scheduling of assets such as naval vessels. Brown, Goodman, and Wood (1990) formulate the problem of scheduling the ships of the U.S. Navy's Atlantic Fleet for training exercises and deployments as a set-partitioning problem. Additionally, Wing (1986) utilizes set-partitioning techniques to develop a generalized model for scheduling naval ships for maintenance, training, and inspections.

IV. IMPLEMENTATION AND RESULTS

The OCPS-ECS model was implemented in the General Algebraic Modeling System or GAMS (Brooke, et al., 1997) and solved using CPLEX Version 6.5 (ILOG, 1999). To validate OCPS-ECS and illustrate its applications, this thesis uses data from a representative Marine officer MOS, 0302-Infantry, described in Section A. Section B presents an algorithm for generating acceptable career paths. Finally, the last two sections, Sections C and D, provide sample outputs from OCPS-ECS and discuss how these outputs can aid in manpower decision-making.

A. INPUT DATA

Data for OCPS-ECS can be categorized into three groups: MOS-related data, user parameters, and career paths. Below is a description of how these data are constructed or obtained from Marine Corps manpower documents for the 0302-Infantry MOS.

1. The MOS-related data include billet requirements, continuation fractions, and limits on the number of newly commissioned officers assigned to a MOS. Each is described below:

a) Billet requirements (or $Rqmt_b$ in OCPS-ECS) for the Infantry MOS are drawn from the current Marine officer staffing goals. Recall from Chapter II that the Marine Corps determines its billet requirements using three sequential processes (i.e., force structure, manning, and staffing) that result in the staffing goals for the assignment of officers to billets. In addition to identifying staffing goals for Infantry-specific billets, the staffing process also specifies staffing goals for billets

requiring a general MOS category such as 9910-Unrestricted officer and 9911-Unrestricted Ground officer. For example, the manning process may specify 200 billets for 9911-Unrestricted Ground officers. It is the staffing process which then designates the portion of these billets to be filled by Infantry officers. (For example, the goal might be to fill 150 of the 200 billets for the 9911 MOS with Infantry officers.) These "general MOS category" staffing goals are then combined with the staffing goals for Infantry-specific billets to arrive at the complete set of billet requirements for the Infantry MOS.

b) Recall from Chapter III that OCPS-ECS approximates the true manpower problem by aggregating billets with similar characteristics. Thus, billets in OCPS-ECS implicitly denote a collection of similar billets. Figure 10 lists some of the individual billets included in an aggregate billet for 0302-Infantry officers called "Instructor Duty". Descriptions of other aggregate billets are listed in Appendix A.

Billet Description	Min Tour (Yrs)	Max Tour (Yrs)	Rank	Requirement
MTN WARF TRNG CTR BRIDGEPORT CA	2	4	Capt	4
EWTGLANT LITTLE CREEK NORFOLK VA	2	4	Capt	2
EWTGPAC CORONADO SAN DIEGO CA	2	4	Lt/Capt	6
MAWTS 1 3DMAW YUMA AZ	2	4	Capt	2
US NAVAL ACADEMY ANNAPOLIS MD	2	4	Capt	6
SCHOOL OF INFANTRY CAMP PENDLETON CA	2	4	Lt/Capt	26
FORMAL SCHOOLS CAMP PENDLETON CA	2	4	Capt	1
SCHOOL OF INFANTRY CAMP LEJEUNE NC	2	4	Lt/Capt	20
FORMAL SCHOOLS CAMP LEJEUNE NC	2	4	Capt	1
USA INF SCHOOL FT BENNING GA	2	4	Capt	1
MARINE CORPS UNIV. QUANTICO VA	2	4	Lt/Capt	54
Instructor Duty (Aggregated Billet)	2	4	Capt	123

Figure 10. The "Instructor Duty" billet is an aggregate billet that denotes a collection of billets with instructional duty and similar tour length and rank requirements.

c) The continuation fractions for the 0302-Infantry MOS ($ContFrac_t$ in OCPS-ECS) are the same as those in Figure 2.

d) The limits (i.e., *Minoff* and *Maxoff* in OCPS-ECS) on the annual number of newly commissioned officers assigned to the Infantry MOS are derived from the Fiscal Year 2000 Officer MOS Classification Plan. These limits are set at 190 and 210 officers, respectively.

e) A career path consists of 30 years. However, billets during the first 15 years of each career path are actual (aggregate) billets as discussed in Item b above. For years 16 to 30, officers on every career path fill the same fictitious billet called "FINAL" billet.

2. The second set of data for OCPS-ECS, user parameters, refers to data that are selected by the user for the particular model application. They include:

a) the penalties ($OverPen_b$ and $UnderPen_b$) for failing to meet or exceeding each billet requirement, respectively

b) the maximum allowable deviations ($OverDev_b$ and $UnderDev_b$) from each billet requirement, respectively

c) the core competency value ($CoreCompPt_b$) for each billet

d) the minimum average core compency points required for an officer career ($MinAvgCCPt$)

e) the minimum and maximum average tour length ($MinAvgTour_b$ and $MaxAvgTour_b$) for each billet requirement

f) the minimum and maximum fill fraction ($MinFillFrac_b$ and $MaxFillFrac_b$) for each billet requirement

Appendix B contains a set of hypothetical user parameters selected for the OCPS-ECS implementation presented in Section C. These values do not reflect the opinion of the Marine Corps. Instead, they are based on the author's perception of current Marine Corps practices.

3. The final set of data, a collection of valid career paths, forms the most important portion of the input data to OCPS-ECS. However, career paths are not readily available, and, therefore, they must be generated from MOS-related data. Section B describes one algorithm for generating career paths for any MOS.

B. CAREER PATH GENERATION

To generate acceptable career paths for OCPS-ECS, this thesis develops a JAVA program called the Career Path Generator (CPG). The program consists of four related elements depicted in Figure 11.

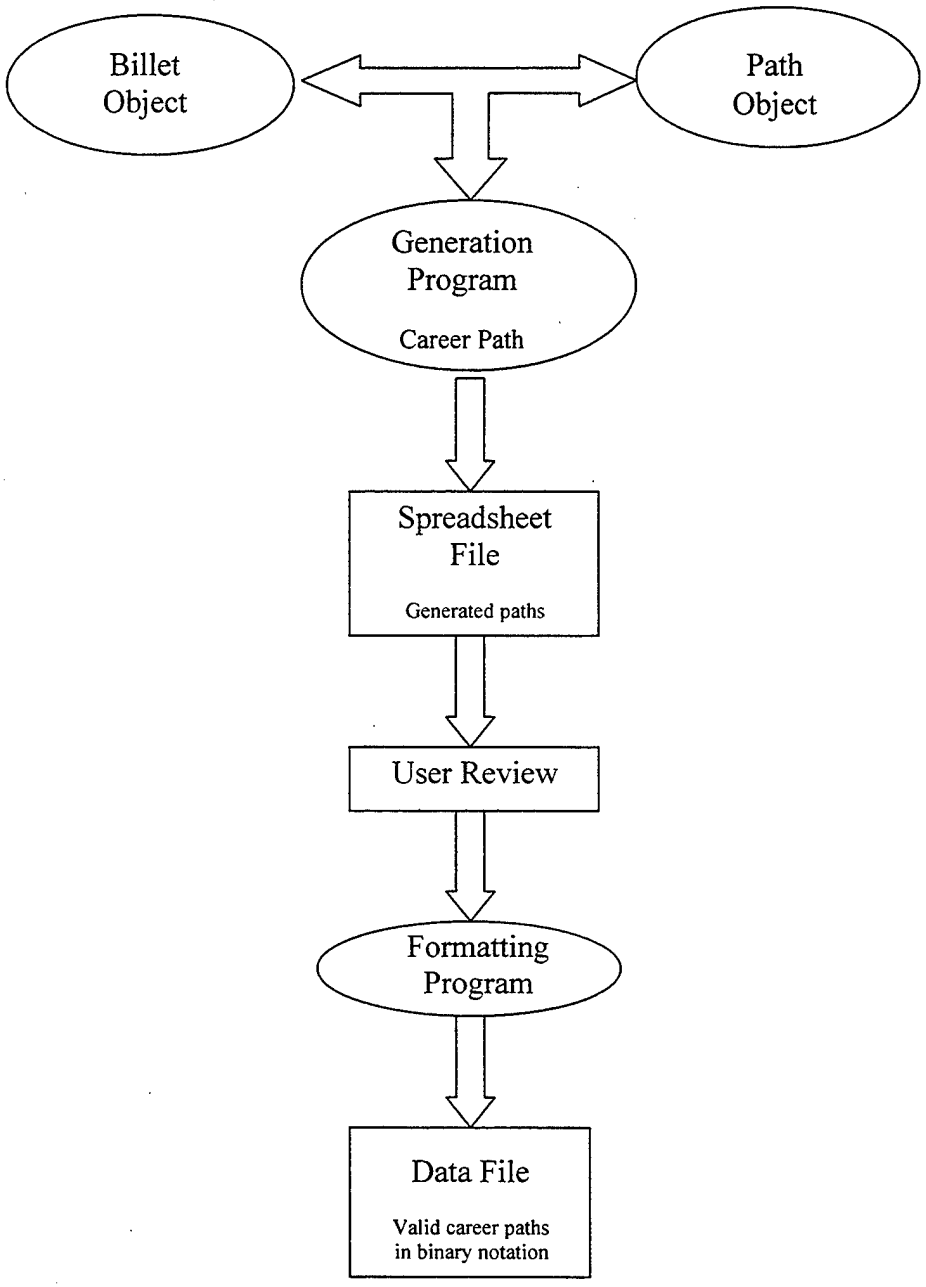

Figure 11. Career Path Generator (CPG). The generation program utilizes the billet and path objects to create a collection of valid career paths. The program outputs a spreadsheet file of generated career paths for subsequent user review and modification. Following user changes, the formatting program accepts as input the spreadsheet file of "approved" career paths and converts them into a format suitable for GAMS.

Below are descriptions of these programming elements.

1. Billet Object: This is an 'object' that contains the billet's attributes (see also Figure 12):

   a) The minimum and maximum YCS required by the billet.

   b) The minimum and maximum tour lengths allowed by the billet.

   c) Special requirements: For example, billet A may require assignment to billet B as a prerequisite. Similarly, prior assignment to billet C may disqualify an officer from subsequently being assigned to billet A.

   d) Possible assignment positions: These are positions in a career path that a billet can occupy. In Figure 12, the "Basic-MOS Training" (or "SCHOOL") billet has assignment position 1 indicating that it can only be designated as an officer's first duty assignment. This billet corresponds to officers attending the Marine Officer Basic School and Infantry Officer Course during their first year of commissioned service. The "Company Commander" billet has two possible assignment positions, i.e., 5 and 6. This indicates that the officer can serve in the "Company Commander" billet during his 5^{th} or 6^{th} duty assignment.

Billet Description	Min YCS (Years)	Max YCS (Years)	Min Tour (Years)	Max Tour (Years)	Pre-requisites	Disqualification	Assignment Position(s)
Basic-MOS Training (SCHOOL)	0	1	1	1	None	None	1
Platoon Commander (PLTCDR)	1	5	2	4	SCHOOL	None	2
Operational 1 (OPER1)	2	5	2	4	PLTCDR	None	3
Recruiting (RECRUIT1)	3	8	2	4	PLTCDR	None	3,4
Instructor Duty (INSTR)	3	8	2	4	PLTCDR	None	3,4
B-Billet 1 (BBILLET1)	3	8	2	4	PLTCDR	None	3,4
Special Eduction Program (SEP)	3	18	5	5	PLTCDR	CLS and ILS	3,4,5,6,7
Career Level School (CLS)	7	9	1	1	PLTCDR	SEP	4,5
Company Commander (COCDR)	8	12	1	3	PLTCDR	None	5,6
Non-Commander (NONCDR)	8	12	1	3	PLTCDR	None	4,5,6,7
Intermediate Level School (ILS)	10	15	1	3	PLTCDR	CLS and ILS	6,7,8
Inspector and Instructor (IANDI)	11	16	2	4	PLTCDR	None	6,7,8,9
Other Post-Command (OTHERPC)	10	16	2	4	PLTCDR	None	6,7,8,9
Operatinal 2 (OPER2)	13	17	2	3	PLTCDR	None	6,7,8,9
Final Billet (FINAL)	15	30	15	15	PLTCDR	None	7,8,9,10

Figure 12. Infantry billet attributes. The first five columns are self-explanatory. The *prerequisite* and *disqualification* columns define the special requirements for a particular billet. For instance, in order for an officer to be assigned to the "Operational 1" billet, he must have had the previous assignment of "Platoon Commander". In the last column, observe that the "Basic-MOS Training" billet has assignment position 1 indicating that it can only be designated as an officer's first duty assignment. However, the "Company Commander" billet has two possible assignment positions, i.e., 5 and 6. This indicates that the officer can serve in the "Company Commander" billet during his 5^{th} or 6^{th} duty assignment.

2. Path Object: This object represents a career path that consists of the following components (see also Figure 13):

a) Billet array: This array is initially empty and used for storing names of billets in the sequence in which they appear in a career path.

b) Tour length array: As in the billet array, this array is initially empty and used for storing the tour lengths associated with each billet in the billet array.

c) Billet count: This is the number of billets in a career path. Initially, the billet count for every path object is zero and increases by one when a new billet is added to the path.

d) YCS count: Initially, it is zero and, as billets are added to a career path, YCS count is the sum of the tour lengths in the tour length array.

Billet Array	Tour Length Array
Basic/MOS Training	1
Platoon Commander	2
Operational 1	2
Instructor Duty	3
Career Level School	1
Company Commander	2
Billet Count = 6	
YCS Count = 11	

Figure 13. An example of a path object. This path contains 6 billets and has a YCS count of 11 years.

3. Generation Program: This is a JAVA program that uses the billet and path objects to create billets and generate acceptable career paths in a spreadsheet format for user review.

4. Formatting Program: This is a JAVA program that converts the acceptable career paths in a spreadsheet format into a format suitable for GAMS.

The generation program employs an algorithm called the Career Path Generation (CPG) Algorithm. The algorithm utilizes a *first-in-first-out* (FIFO) queue that initially contains only a single "empty" path object (i.e., one with billet and YCS counts of zero). By removing this path from the queue and appending it with all valid first billet assignments and tour lengths, the algorithm creates a series of incomplete career paths that are then returned to the queue. In such a manner, the algorithm repeatedly removes,

appends, and returns paths to the queue. When the addition of a billet assignment and tour length combination completes a path (i.e., it reaches 30 YCS), the complete career path is placed in an output array instead of the FIFO queue. The algorithm terminates when there are no longer any paths on the FIFO queue. Below is a formal statement of the Career Path Generation Algorithm.

Career Path Generation Algorithm

Step 0: For each billet, create a billet object with corresponding attributes. Then, create an "empty" path object and place it on a FIFO queue.

Step1: If the FIFO queue is empty, stop. Otherwise, remove path p from the top of the queue.

Step 2: Let α and β be the billet and the YCS counts associated with path p, respectively. Find a billet b with all of the following characteristics:

a) One of its possible assignment positions is $(\alpha + 1)$,
b) β is within the minimum and maximum YCS required by billet b,
c) Billets in path p satisfy billet b's requirements.

If none is found, discard path p and return to Step 1. Otherwise, go to Step 3.

Step 3: Let k and l denote the minimum and maximum tour lengths for billet b. For $j = k$, $(k + 1),\ldots, l$, if $(\beta + j) \leq 30$, then do the following:

Make a copy of path p and call it q. Add billet b with tour length j to path q. If $(\beta + j) < 30$, place the newly augmented path q on the FIFO queue. Otherwise (i.e., $\beta + j = 30$), place path q in an output array because it is a full career path.

Go to Step 1.

Observe that the algorithm removes the path, p, at the top of the queue in Step 1 and tries to find a compatible billet to append in Step 2. If a compatible billet, b, is found, several new paths may be generated by appending billet b to path p, each time with a different tour length. In Step 3, appended paths with less than 30 YCS are placed on the FIFO queue to germinate more paths, while the remainder are placed in an output array because they constitute full career paths, i.e., ones with 30 YCS.

Figure 14 displays a part of the output file produced by CPG (truncated to the first eleven years of commissioned service). The user can examine and selectively delete those that are not suitable for Infantry officers. Afterward, CPG converts the modified output file into a data file that is suitable for GAMS.

Path	YCS 1	YCS 2	YCS 3	YCS 4	YCS 5	YCS 6	YCS 7	YCS 8	YCS 9	YCS 10	YCS 11
1	SCHOOL	PLTCDR	PLTCDR	PLTCDR	RECRUIT1	RECRUIT1	RECRUIT1	RECRUIT1	CLS	COCDR	COCDR
2	SCHOOL	PLTCDR	PLTCDR	PLTCDR	RECRUIT1	RECRUIT1	RECRUIT1	RECRUIT1	CLS	COCDR	COCDR
3	SCHOOL	PLTCDR	PLTCDR	PLTCDR	RECRUIT1	RECRUIT1	RECRUIT1	RECRUIT1	CLS	COCDR	COCDR
4	SCHOOL	PLTCDR	PLTCDR	PLTCDR	RECRUIT1	RECRUIT1	RECRUIT1	RECRUIT1	CLS	COCDR	COCDR
5	SCHOOL	PLTCDR	PLTCDR	PLTCDR	INSTR	INSTR	INSTR	CLS	COCDR	COCDR	ILS
6	SCHOOL	PLTCDR	PLTCDR	PLTCDR	INSTR	INSTR	INSTR	CLS	COCDR	COCDR	ILS
7	SCHOOL	PLTCDR	PLTCDR	PLTCDR	INSTR	INSTR	INSTR	CLS	COCDR	COCDR	ILS
8	SCHOOL	PLTCDR	PLTCDR	PLTCDR	INSTR	INSTR	INSTR	CLS	COCDR	COCDR	OTHERPC
9	SCHOOL	PLTCDR	PLTCDR	PLTCDR	INSTR	INSTR	INSTR	CLS	COCDR	COCDR	OTHERPC

Figure 14. Sample output for the Career Path Generator. Each row represents a career path and each column corresponds to a year in the path. For example, officers in path 1 attend the Marine Officer Basic School and the Infantry Officer Course during the first year. The officers are then assigned to a platoon commander (PLTCDR) billet for the next three years. Thereafter, they serve in a recruiting billet (RECRUIT1) for the next four years. Billet assignments continue in a similar fashion until the career path reaches thirty years of commissioned service.

C. SAMPLE OUTPUT

Using the Infantry MOS data presented in Section A (see Figure 12) as input, the CPG generated 18,561 suitable Infantry officer career paths with core competency values ranging from 4.7 to 9.9. This set of career paths along with the MOS-related data and user parameters discussed in Section A (and summarized in Appendix B) are used as inputs for OCPS-ECS. Using a Pentium III (500 MHz) computer with 392 megabytes of random access memory, GAMS required 17.3 minutes of CPU time to generate the resulting OCPS-ECS problem and the CPLEX solver found a solution within 1% of the true optimal solution in less than five minutes of CPU time. Below are some outputs from solving a single instance of OCPS-ECS.

The "optimal" solution recommends that 190 officers be annually assigned, or *accessed*, to the Infantry MOS. As shown in Figure 15, OCPS-ECS assigns the 190 Infantry officers to 16 of the possible 18,651 career paths. These 16 career paths can be partitioned into two distinct groups. One consists of those with at most two officers assigned to them (i.e., 1, 3, 4, 7, 9, 11, 14, 15, and 16) and the other consists of those with at least nine officers (i.e., 2, 5, 6, 8, 10, 12, and 13). The latter are referred to herein as "principal" career paths and, when combined, they account for approximately 95% of the career path assignments (i.e., 180 of the 190 Infantry officers accessed annually).

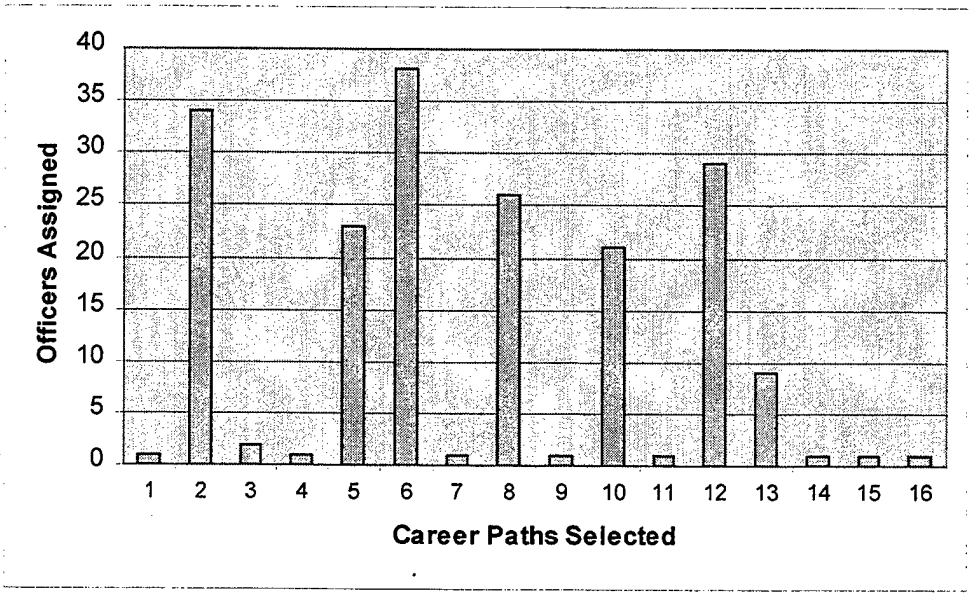

Figure 15. Career paths selected by OCPS-ECS. The "optimal" solution uses 16 of the possible 18,561 career paths. Observe that seven of the paths (i.e., 2, 5, 6, 8, 10, 12, and 13) comprise 94.7% (180 of 190) of the annual officer career path assignments. The remaining nine paths (i.e., 1, 3, 4, 7, 9, 11, 14, 15, and 16) account for the other 5.3% (10 of 190) of the assignments.

Examining the "optimal" solution more closely suggests that principal career paths are selected mainly to minimize deviations from the specified billet requirements (i.e., to improve the objective function). By themselves, principle career paths cannot quite satisfy constraints such as average core competency and billet tour length requirements.

It is the non-principal career paths that help bridge these gaps to create a feasible solution.

Figure 16 displays the billets that comprise each of the seven principal career paths. (For a complete list of (aggregated) billets along with their respective abbreviations, see Figure 12.) As discussed in Section A, each career path makes an assignment to the FINAL billet for YCS 16 to YCS 30. Additionally, each path begins with assignments to the SCHOOL and PLTCDR billets in YCS 1 and YCS 2, respectively. However, the characteristics of principal career paths can be distinctly different. For instance, path 2 assigns each officer to the PLTCDR billet, a billet in the Fleet Marine Force (defined in Section C of Chapter II), for two years followed by a four-year assignment in a Supporting Establishment billet called RECRUIT1. Path 5, on the other hand, assigns each officer to a four-year tour in the PLTCDR billet followed by only a two-year tour in BBILLET1, another Supporting Establishment billet. Finally, career paths in Figure 16 also exhibit an interesting pattern. When included in a career path, the CLS billet always occurs during the 8^{th} year of an officer's career. A similar observation also applies to the ILS billet that occurs during the 11^{th} year of an officer's career. This is approximately what currently occurs in practice and empirically justifies the choice of user parameters listed in Appendix B.

Paths:	Path 2	Path 5	Path 6	Path 8	Path 10	Path 12	Path 13
Assigned:	34	23	38	26	21	29	9
YCS 1	SCHOOL	SCHOOL	SCHOOL	SCHOOL	SCHOOL	SCHOOL	SCHOOL
YCS 2	PLTCDR	PLTCDR	PLTCDR	PLTCDR	PLTCDR	PLTCDR	PLTCDR
YCS 3	PLTCDR	PLTCDR	OPER1	PLTCDR	PLTCDR	PLTCDR	PLTCDR
YCS 4	RECRUIT1	PLTCDR	OPER1	RECRUIT1	INSTR	BBILLET1	SEP
YCS 5	RECRUIT1	PLTCDR	OPER1	RECRUIT1	INSTR	BBILLET1	SEP
YCS 6	RECRUIT1	BBILLET1	INSTR	INSTR	INSTR	BBILLET1	SEP
YCS 7	RECRUIT1	BBILLET1	INSTR	INSTR	INSTR	BBILLET1	SEP
YCS 8	CLS	CLS	CLS	INSTR	CLS	CLS	SEP
YCS 9	NONCDR	COCDR	COCDR	COCDR	NONCDR	COCDR	NONCDR
YCS 10	NONCDR	COCDR	COCDR	COCDR	COCDR	COCDR	COCDR
YCS 11	OTHERPC	OTHERPC	COCDR	ILS	OTHERPC	ILS	ILS
YCS 12	OTHERPC	OTHERPC	IANDI	IANDI	OTHERPC	IANDI	OTHERPC
YCS 13	OTHERPC	OTHERPC	IANDI	IANDI	OTHERPC	IANDI	OTHERPC
YCS 14	OPER2	OPER2	OPER2	OPER2	OPER2	OPER2	OPER2
YCS 15	OPER2	OPER2	OPER2	OPER2	OPER2	OPER2	OPER2
YCS 16	FINAL	FINAL	FINAL	FINAL	FINAL	FINAL	FINAL
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
YCS 30	FINAL	FINAL	FINAL	FINAL	FINAL	FINAL	FINAL

Figure 16. The seven principal career paths selected by OCPS-ECS. Observe that each career path includes an assignment to the FINAL billet for YCS 16 to YCS 30. Additionally, each of the career paths has assignments to the SCHOOL billet in YCS 1 and the PLTCDR billet in YCS 2. Note also that those career paths that make assignments to the CLS billet (i.e., paths 2, 5, 6, 10, and 12) or the ILS billet (i.e., paths 8, 12, and 13) do so in the same year (i.e., YCS 8 and YCS 11, respectively).

Given the career path assignments in Figure 15, Figure 17 graphically shows how well those assignments meet the specified billet requirements. Observe that the billets with the highest penalty values (see Appendix B), i.e., PLTCDR, COCDR and OPER2, receive 100% of their officer requirements. However, the number of officers assigned to other billets may be more or less than the respective number required. For instance, the total number of officers assigned to the Supporting Establishment billets (i.e., RECRUIT1, INSTR, and BBILLET1) is 140% of their combined requirement. On the other hand, the number of officers assigned to the Post-Command billets (i.e., OTHERPC, OPER2, and IANDI) is only 67% of their combined requirement.

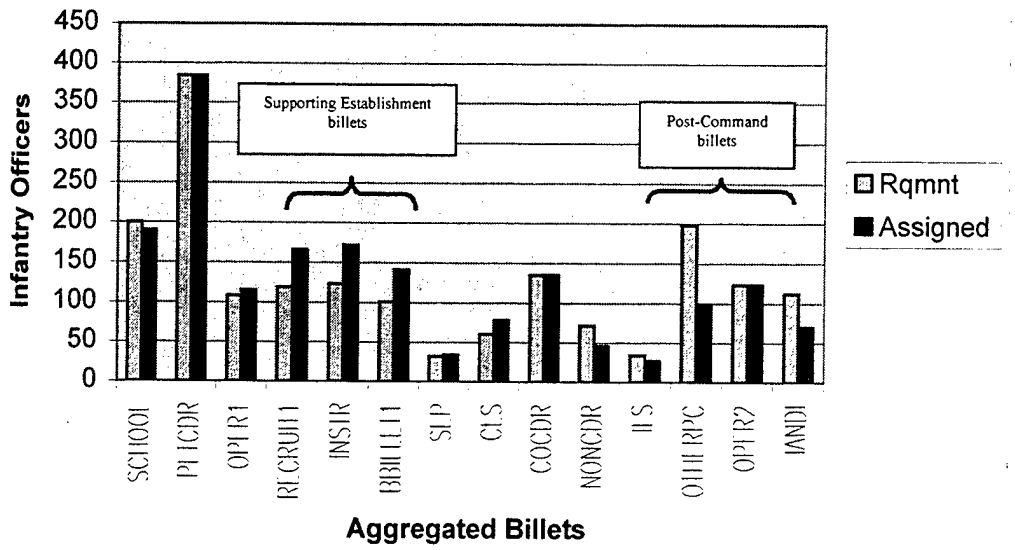

Figure 17. Officer assignments versus billet requirements. For the most heavily penalized billets (i.e., PLTCDR, COCDR, and OPER2), the number of officers assigned to each matches the respective number required. For other billets, the number assigned varies in comparison to the respective requirement. For instance, the number of officers assigned to the Supporting Establishment and Post-Command billets is 140% and 67% of the billet requirements, respectively.

Figure 18 displays the number of officers assigned to each of the selected career paths along with the respective path's core competency value. Observe that nearly one-third of the officers (62 of 190) are assigned to the career paths with the three highest core competency values. The lowest core competency value among the 16 selected career paths is 5.45.

Career Path	Core Competency Value	Officers Assigned	Cumulative % of Assigned Officers
16	8.75	1	0.53%
6	8.65	38	20.53%
5	8.15	23	32.63%
9	8.05	1	33.16%
3	7.40	2	34.21%
7	7.25	1	34.74%
8	7.25	26	48.42%
12	7.05	29	63.68%
14	6.95	1	64.21%
11	6.85	1	64.74%
15	6.85	1	65.26%
1	6.75	1	65.79%
2	6.65	34	83.68%
10	6.65	21	94.74%
4	5.90	1	95.26%
13	5.45	9	100.00%

Figure 18. Number of officers assigned versus core competency value for the sixteen career paths selected by OCPS-ECS. Observe that nearly one-third (62 of 190) of the officers are assigned to the career paths with the three highest core competency values.

OCPS-ECS output also yields the *billet assignment rate* (or percentage) which is the likelihood that an officer will receive an assignment to a given billet during his or her career. Some billets are important for advancement (promotion), while others are required for every officer. Those that are essential for advancement should have a high billet assignment rate to ensure that a greater number of officers are competitive for promotion. Algebraically, the billet assignment rate is defined as follows:

$$\text{Billet Assignment Rate for billet } b \quad = \quad \frac{\sum_{p \in CP} \{ASSIGN_p * InPath_{p,b}\}}{\sum_{p \in CP} ASSIGN_p},$$

where $ASSIGN_p$ is an optimal number of officers assigned to path p and $InPath_{p,b}$ is as defined in Chapter III. Figure 19 displays the billet assignment rates for the aggregated billets considered in the model (see Figure 12). The billet assignment rates for the

SCHOOL and PLTCDR billets are 1.0 because every Infantry officer must attend the Marine Officer Basic School-Infantry Officer Course (SCHOOL) and serve in a platoon commander billet (PLTCDR). In Figure 19, career enhancement billets, such as COCDR and OPER2, have the highest billet assignment rates exclusive of the required SCHOOL and PLTCDR billets.

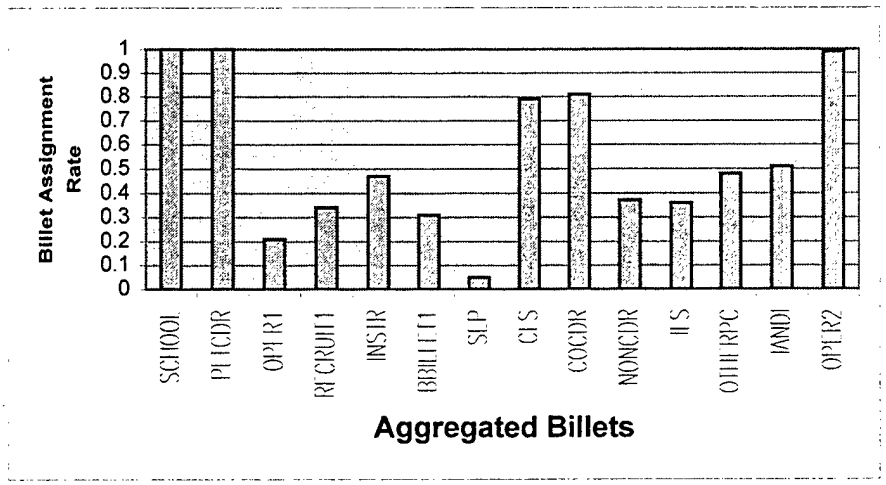

Figure 19. Billet assignment rates. A value of 1.0 indicates that the respective billet is included in every career path of the "optimal" solution. Observe that every Infantry officer attends the Marine Officer Basic School-Infantry Officer Course (SCHOOL) and serves in a platoon commander billet (PLTCDR). Additionally the COCDR and OPER2 billets, which can enhance an officer's advancement opportunity, have high billet assignment rates.

For the set of 16 career paths selected by OCPS-ECS, Figure 20 displays the average tour length and time (in terms of YCS) at which an officer is assigned to each billet. Comparing these two averages to what actually occurs in practice is useful in verifying the model's correctness and validating the choice of user parameters. For example, officers are assigned to the COCDR billet at 8.20 YCS on average. The average tour length in the COCDR billet is 2.07 years. These values, as well as the others shown in Figure 20, seem to match this author's perception of current Infantry officer career paths.

Billet	Average Tour Length (year)	Average Time (YCS)
SCHOOL	1.00	0.00
PLTCDR	2.04	1.00
OPER1	3.00	2.00
RECRUIT1	3.09	3.08
INSTR	2.76	4.56
BBILLET1	3.10	3.85
SEP	5.00	3.00
CLS	1.00	7.00
COCDR	2.07	8.20
NONCDR	1.53	8.10
ILS	1.00	10.06
OTHERPC	2.89	10.11
IANDI	2.01	11.01
OPER2	1.99	13.01

Figure 20. Average tour length and time (in terms of YCS) at which an officer is assigned to each billet. For example, the average tour length for the COCDR billet is 2.07 years and an officer is assigned to the billet at 8.20 YCS on average.

D. SAMPLE APPLICATIONS

To illustrate how OCPS-ECS can aid in decision-making, this section presents three potential applications. Results from OCPS-ECS in these applications are guaranteed to be within 2% of an optimal solution.

1. Number of Officers to Annually Access to the Infantry MOS

Recall that the optimal solution in Section C annually accesses 190 officers to the Infantry MOS. However, this number coincides with the lower limit derived from the Fiscal Year 2000 Officer MOS Classification Plan (i.e., *MinOff* in the OCPS-ECS formulation). To determine whether it is possible to better meet billet requirements by accessing fewer officers to the Infantry MOS, the following constraint was removed from

OCPS-ECS and the problem was re-solved using the input data in Section A (see also Appendix B).

$$MinOff \leq \sum_{p \in CP} ASSIGN_p$$

An "optimal" solution to the modified OCPS-ECS only accesses 169 officers to the Infantry MOS. When compared to 190 officers, this is approximately an 11% reduction. (In practice, the 21 officers not annually accessed to the Infantry MOS would be assigned to another MOS.) Comparing the results in Figure 22 with those in Figure 17, a reduction in Infantry accessions to 169 officers decreases the number of officers assigned to Supporting Establishment billets from 480 (or 140% of the requirement) in Figure 17 to 371 (or 108% of the requirement) in Figure 22. Similarly, the number of officers assigned to the Post-Command billets also decreases from 292 (or 67% of the requirement) in Figure 17 to 235 (or 54% of the requirement) in Figure 22. In this case, by annually accessing 169 Infantry officers instead of 190, the officer assignment shortfalls in the Post-Command billets are exacerbated. To remedy this, the next application investigates the effects of meeting a certain percentage of Post-Command billet requirements.

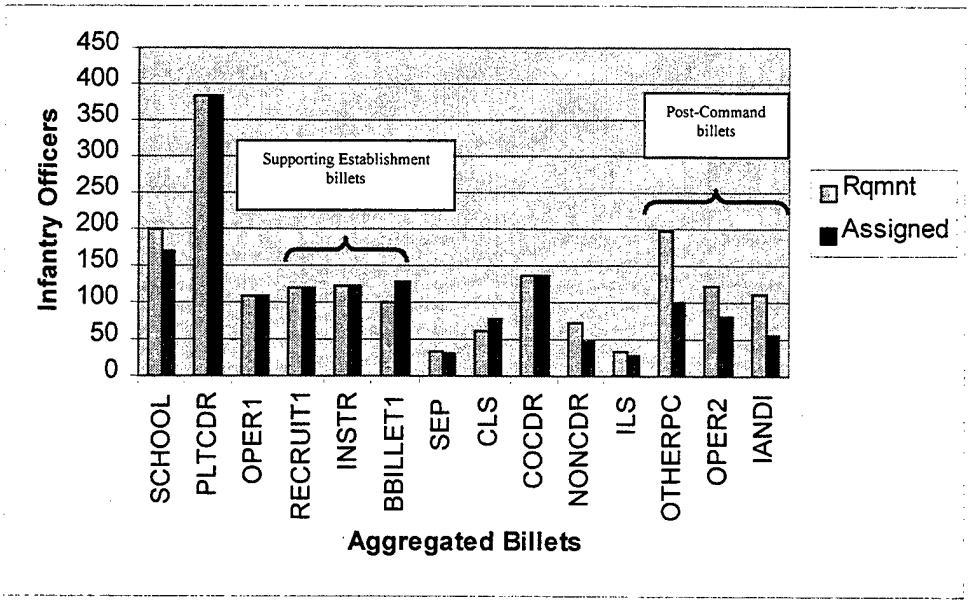

Figure 22. Officer assignments versus billet requirements. When compared to the results in Figure 17, the modified OCPS-ECS annually assigns fewer officers (169 versus 190) to the Infantry MOS and the billet requirements for the Supporting Establishment billets (i.e., RECRUIT1, INSTR, and BBILLET1) are better met. On the other hand, Post-Command billets (i.e., OTHERPC, OPER2, and IANDI) suffer greater shortfalls.

2. Relationship between Supporting Establishment and Post-Command Billets

To quantify the effects of meeting a certain percentage of the Post-Command billet requirements, the allowable shortfall ($UnderDev_b$) was varied from 0 to 25% of the requirement of each Post-Command billet, i.e., each billet $b \in$ {OTHERPC, OPER2, and IANDI}. To ensure that a feasible solution exists, the constraint limiting the number of officers assigned to each billet over its requirement, i.e.,

$$OVER_b \leq OverDev_b, \qquad \forall b,$$

was eliminated from OCPS-ECS.

Figure 23 displays the annual number of Infantry officer accessions and percent deviations from billet requirements that result from solving the modified OCPS-ECS with six different values of allowable shortfall ($UnderDev_b$). As the amount of allowable

shortfall decreases to zero, the number of annual Infantry officer accessions increases from 200 to 260 officers. This increase in officer accessions causes the excess number of officers in the Supporting Establishment billets to increase from 48.51% to 105.84% over the requirements. The last column in Figure 23 verifies that the percent deviations from the Post-Command billet requirements are within the allowable amounts (i.e., the $UnderDev_b$ values listed in the first column of the figure). Because optimal solutions to optimization problems, integer programs in particular, do not satisfy every constraint with equality, the resulting percent deviations for the Post-Command billets do not match $UnderDev_b$.

$UnderDev_b$ (% of Rqmt)	Officers Accessed	Pecent Deviation from Rqmt SPT ESTAB	POST-CMD
0.25	200	48.51%	-24.59%
0.20	212	59.81%	-19.59%
0.15	234	71.10%	-14.65%
0.10	236	82.40%	-9.75%
0.05	248	93.70%	-4.82%
0.00	260	105.84%	0.11%

Figure 23. Restricting the amount of allowable shortfall ($UnderDev_b$) for Post-Command billets. As the allowable shortfall decreases from 25% to 0% of the number required, the number of Infantry officer accessions increases from 200 to 260. As a consequence, the excess number of officers assigned to Supporting Establishment billets increases from 45.51% to 105.84% over the requirement. The last column verifies that the shortfalls of the Post-Command billets are within the allowable amounts as listed in the first column.

One possible explanation for the large increase in the excess number of officers assigned to the Supporting Establishment billets is the fact that OCPS-ECS data for billet requirements are derived from the staffing process. Recall that the staffing process determines billet requirements by reconciling the manning requirements with the size and composition of the current officer inventory. However, the original and modified versions of OCPS-ECS address both the current and the future officer inventory. In

OCPS-ECS, the size and composition of the future officer inventory are estimated from the officer continuation rate forecasts (see Figure 2). When these forecasts differ significantly from the current inventory, there could be large deviations from specified billet requirements such as those in Figure 23.

3. Effects of Increasing Core Competency Requirements

As discussed in Chapters I and II, the Marine Corps Manpower System seeks to meet its primary objective of fulfilling current billet requirements while simultaneously developing officer core competency. OCPS-ECS provides a means of determining the effects on critical billets (e.g., PLTCDR and COCDR) in the event that the Marine Corps chooses to increase the minimum average core competency requirement (*MinAvgCCPt*) for the career paths selected by OCPS-ECS.

Figure 24 displays results from solving OCPS-ECS six times with *MinAvgCCPt* varied from 8.0 to 8.5. To achieve higher core competency values, OCPS-ECS assigns more officers to the PLTCDR billet for a longer period of time. In fact, the percentage of officers assigned to the billet increases from 99.95% to 125.22% of its requirement. Similarly, the average tour length in the billet also increases from 2.04 to 2.57 years. As listed in Appendix B, the PLTCDR billet has a relatively high core competency value. To increase the average core competency value for the selected career paths, it is therefore logical for OCPS-ECS to assign more officers to such a billet for a longer period of time.

MinAvgCCPt	PLTCDR Percent of Requirement	Avg PLTCDR Tour Length (years)	Avg COCDR Tour Length (years)	COCDR Assignment Rate
8.00	99.95%	2.04	2.16	0.77
8.10	100.80%	2.06	2.03	0.83
8.20	106.14%	2.17	1.68	1.00
8.30	114.01%	2.34	1.68	1.00
8.40	123.83%	2.55	1.68	1.00
8.50	125.22%	2.57	1.68	1.00

Figure 24. Effects on the PLTCDR and COCDR billets by varying the minimum average core competency requirement (*MinAvgCCPt*). Because of the high core competency value of the PLTCDR billet, OCPS-ECS assigns it more officers for a longer period of time. The effect on the COCDR billet is an increase in its assignment rate from 0.77 to 1.00 and an undesirable decrease in its average tour length from 2.16 to 1.68 years.

As in Section C, OCPS-ECS continues to meet the requirement for the COCDR billet exactly for all minimum core competency values in Figure 24. This is because COCDR has the highest penalty values, i.e., $OverPen_b$ and $UnderPen_b$. On the other hand, OCPS-ECS has to increase the billet assignment rate for COCDR from 0.77 to 1.00 in order to meet the higher core competency requirement. The assignment rate of 1.00 means that every Infantry officer now holds the COCDR billet at some point during his career. Because the requirement for COCDR is constant at 135 officers, allowing every officer to serve in the COCDR billet can only be accomplished by shortening the billet's average tour length from 2.16 to 1.68 years. Thus, results from OCPS-ECS show that increasing the minimum core competency value from 8.00 to 8.20 (or by 2.5%) has the undesired effect of decreasing the average tour length for the COCDR billet by 0.48 years (or 22.22%).

V. CONCLUSIONS AND RECOMMENDATIONS

This thesis presents an integer program called the Officer Career Path Selection (OCPS) model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. To make OCPS numerically tractable, this thesis assumes that billets with similar attributes are aggregated. In a smaller version of OCPS, i.e., OCPS with equal cohort size or OCPS-ECS, the number of officers assigned to the MOS under consideration is the same every year.

To validate OCPS-ECS and illustrate its usefulness in decision-making, this thesis uses data from the 0302-Infantry MOS, hypothetical user parameter values, and a suppositional billet aggregation scheme. OCPS-ECS was implemented in an algebraic modeling system called GAMS. Using a Pentium III (500MHz) computer with 392 megabytes of random access memory, GAMS generates typical OCPS-ECS problems for the Infantry MOS in less than 20 minutes of CPU time and an optimization software package called CPLEX usually solves each generated problem in approximately five CPU minutes.

In addition to providing and describing useful information obtainable from OCPS-ECS, this thesis considered three applications. For the first application, OCPS-ECS helps to determine the number of officers to assign to the Infantry MOS each year. The second application uses OCPS-ECS to analyze the effects of decreasing the allowable shortfalls in a group of billets called the Post-Command billets. Based on the hypothetical user parameter values and the suppositional billet aggregation scheme, results from OCPS-ECS suggest that such a decrease can cause a dramatic increase in the number of officers

assigned to another group of billets called the Supporting Establishment billets. This increase varies from approximately 48% to 105% over the total requirement for the Supporting Establishment billets. Finally, the last application examines the consequence of increasing the average core competency requirement for career paths in the solution to OCPS-ECS. In this case, results from OCPS-ECS indicate that more officers must be assigned to a critical (aggregate) billet, called the Platoon Commander billet, for longer periods of time in order to achieve higher core competency values. Unfortunately, accompanying this increase in assignments to the Platoon Commander billet is an undesirable decrease in the average tour length in another (aggregate) billet called the Company Commander billet.

In addition to the above applications, the following are also possible:

1. Determining the set of continuation rates that best meet the anticipated billet requirements for officers in a selected MOS.

2. Assessing the effect of new billet requirements on Marine Corps operational readiness as measured by, e.g., the manpower system's ability to simultaneously meet both existing and proposed billet requirements.

3. Quantifying the effects of new or, perhaps, non-traditional career paths on Marine Corps operational readiness.

APPENDIX A. BILLET AGGREGATION SCHEME

Billet Description	Requirement
Basic-MOS Training (SCHOOL)	200
Platoon Commander (PLTCDR)	384
Operational 1 (OPER1)	108
Recruiting (RECRUIT1)	119
Instructor Duty (INSTR)	123
B-Billet 1 (BBILLET1)	101
Special Eduction Program (SEP)	32
Career Level School (CLS)	60
Company Commander (COCDR)	135
Non-Commander (NONCDR)	71
Intermediate Level School (ILS)	34
Inspector and Instructor (IANDI)	112
Operatinal 2 (OPER2)	123
Other Post-Command (OTHERPC)	198

To provide the reader an understanding of the billet aggregation scheme used in this thesis, each aggregated billet is described below. Beneath each aggregated billet are the "categories" of billets that it contains. Categories that include distinctly different Infantry officer billets (in terms of duty assignments and rank requirements), such as Headquarters Marine Corps, may be listed under more than one aggregated billet.

Basic-MOS Training (SCHOOL)
- The Basic School
- Infantry Officer Course

Platoon Commander (PLTCDR)
- Platoon Commander (Infantry Battalion)
- Company Executive Officer

Operational 1 (OPER1)

- Light Armored Reconnaissance
- Marine Corps Security Forces (MCSF)
- Force Reconnaissance
- Division Reconnaissance
- Division/MEF Staffs

Recruiting 1 (RECRUIT1)

- Marine Corps Recruit Depots
- Officer Selection Teams
- Naval Reserve Officer Training Corps
- Marine Corps Recruiting Stations
- Marine Corps Recruiting District Staff
- Marine Corps Recruiting Command Staff

Instructor Duty (INSTR)

- Mountain Warfare Training Center
- Expeditionary Warfare Training Groups
- Marine Aviation Weapons Training Squadron
- Service Academies
- Schools of Infantry
- Formal Schools (Camp Pendleton and Camp Lejeune)
- US Army Infantry School
- Marine Corps University

B-Billet 1 (BBILLET1)

- Marine Barracks
- Marine Corps Combat Development Command
- Marine Corps Systems Command
- Foreign Exchange Program
- Headquarters Marine Corps
- Marine Corps Security Guard Battalion
- Foreign Technical Assistance
- Military Observers
- Naval Construction Regiments
- Marine Corps Bases

Special Education Program (SEP)

- Naval Postgraduate School
- Civilian Postgraduate Institutions

Career Level School (CLS)

- Amphibious Warfare School
- Command and Control Systems Course
- US Army Armor School
- US Army Field Artillery School
- US Army Infantry School

Company Commander (COCDR)

- Company Command (Infantry Battalion)
- Other Company Commands

Non-Command (NONCDR)

- Commander Marine Forces Pacific or Atlantic Staff
- Marine Expeditionary Force Staff
- Marine Expeditionary Unit Staff
- Division Staff
- Force Service Support Group Staff
- Infantry Battalion Operations Officer

Intermediate Level School (ILS)

- Command and Staff College
- US Army Command and Staff College
- College of Naval Command and Staff

Inspector and Instructor (IANDI)

- Naval Reserve Officer Training Corps
- Marine Corps Recruiting Stations
- Marine Corps Recruiting District Staff
- Marine Corps Recruiting Command Staff
- Inspector and Instructor Staffs

Operational 2 (OPER2)

- Light Armored Reconnaissance Battalion
- Force Reconnaissance
- Marine Corps Security Forces
- Commander Marine Forces Pacific or Atlantic Staff
- Marine Expeditionary Force Staff
- Marine Expeditionary Unit Staff
- Division Staff
- Force Service Support Group Staff
- Infantry Battalion Operations Officer

Other Post-Command (OTHERPC)

- Marine Corps Recruit Depots
- Mountain Warfare Training Center
- Expeditionary Warfare Training Groups
- Marine Aviation Weapons Training Squadron
- Service Academies
- Schools of Infantry
- Marine Corps University
- Marine Corps Bases
- Marine Barracks
- Marine Corps Combat Development Command
- Marine Corps Systems Command
- Foreign Exchange Program
- Headquarters Marine Corps
- Foreign Technical Assistance
- Military Observers
- Naval Construction Regiment

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APPENDIX B. USER PARAMETERS FOR INFANTRY MOS

Billet Description	*OverPen*	*UnderPen*	*OverDev*	*UnderDev*	*MinAvgTour*	*MaxAvgTour*	*MinFillFrac*	*MaxFillFrac*	*CoreCompPt*
Basic-MOS Training (SCHOOL)	0.00	0.00	1.00	1.00	N/A	N/A	N/A	N/A	0.00
Platoon Commander (PLTCDR)	0.80	0.90	0.25	0.15	2.00	N/A	N/A	N/A	0.80
Operational 1 (OPER1)	0.75	0.85	0.25	0.15	N/A	N/A	N/A	N/A	0.70
Recruiting (RECRUIT1)	0.55	0.65	0.40	0.30	N/A	N/A	N/A	N/A	0.30
Instructor Duty (INSTR)	0.50	0.60	0.40	0.30	N/A	N/A	N/A	N/A	0.20
B-Billet 1 (BBILLET1)	0.40	0.50	0.40	0.30	N/A	N/A	N/A	N/A	0.15
Special Eduction Program (SEP)	0.70	0.10	0.70	0.40	N/A	N/A	N/A	0.05	0.00
Career Level School (CLS)	0.10	0.30	0.30	0.20	N/A	N/A	0.50	N/A	0.40
Company Commander (COCDR)	0.90	1.00	0.25	0.15	1.50	N/A	0.75	N/A	1.00
Non-Commander (NONCDR)	0.20	0.40	0.45	0.35	N/A	N/A	N/A	N/A	0.60
Intermediate Level School (ILS)	0.10	0.30	0.30	0.20	N/A	N/A	N/A	N/A	0.50
Inspector and Instructor (IANDI)	0.65	0.75	0.40	0.50	N/A	N/A	N/A	N/A	0.60
Other Post-Command (OTHERPC)	0.50	0.60	0.45	0.50	N/A	N/A	N/A	N/A	0.50
Operatinal 2 (OPER2)	0.75	0.85	0.40	0.35	N/A	N/A	N/A	N/A	0.75

Note that an "N/A" entry indicates that no constraint containing the parameter in question is specified in the OCPS-ECS implementation.

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